JBCA astrophysics and IRIS

Rob Beswick

(Head of e-MERLIN/VLBI Science operations and support)

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IRIS users via JBCA

IRIS usages cuts across various areas linked to JBCA-ICE (Interferometry Centre of Excellence) – range of users and use-cases, supporting diverse international user communities.

STFC supported international open-user facilities:

e-MERLIN/VLBI -UK National Radio Astronomy Facility – www.e-merlin.ac.uk

ALMA UK Reg. Centre – www.alma.ac.uk

High compute demand analysis:
Extending services and science

e-MERLIN/VLBI, ALMA, LOFAR, MeerKat etc

SKA-related developments:

- SKA SDP software testing and use for existing pathfinder and precursors (inc. e-MERLIN, etc …)
- SKA-SRC…

SKA SQUARE KILOMETRE ARRAY
www.skatelescope.org

A cohesive approach – bring together expertise and proven track record from multi-instrument support, operations and development → enhancing services, community support and science

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e-MERLIN /VLBI -
UK's National radio Astronomy Facility

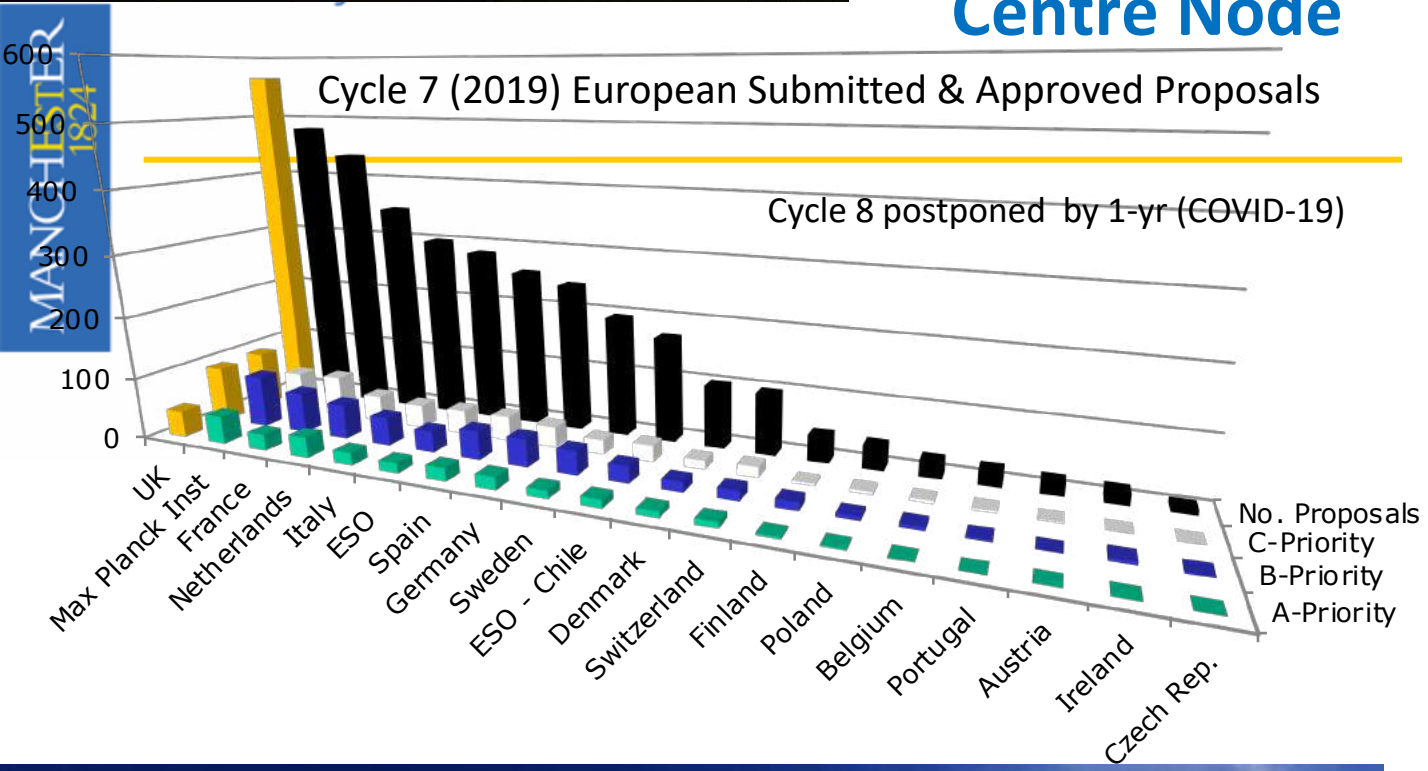
e-MERLIN (SKA-pathfinder) operating at cm-λ with μJy sensitivity and ~10-220km baselines

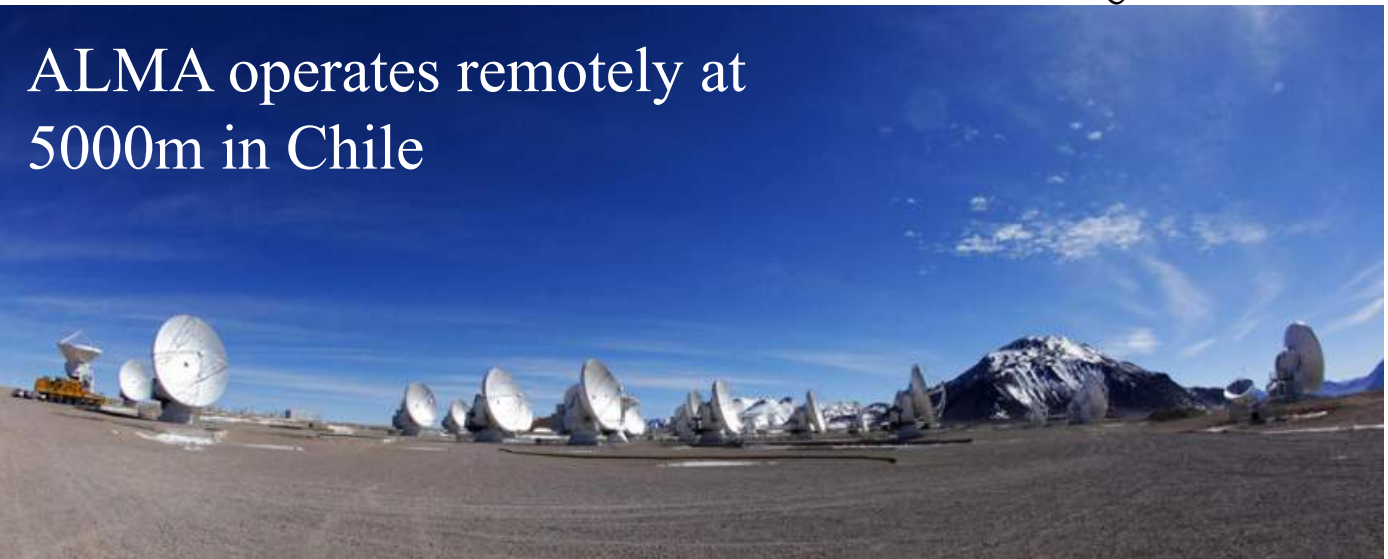
Key/integral part of the EVN - providing 'short' spacing baselines

- fully integrated operations
- e-MERLIN+EVN
- Baselines 10 to 10,000 km

e-MERLIN is a scientific and technical SKA-pathfinder – match in baseline lengths and frequencies to SKA1-mid – ideal science (& technical) test bed

UK ALMA Regional Centre Node





User Support for ALMA programmes across European Support Nodes

Individual F2F support for each proposal from proposal submission, through scheduling, calibration, imaging, and science delivery

Large active mm /sub-mm research groups in the UK

HPC imaging required for major ALMA programmes and for large spectral cubes and image mosaics

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e-MERLIN/ALMA Lifecycle -facility support and roles

e-MERLIN/VLBI & ALMA :

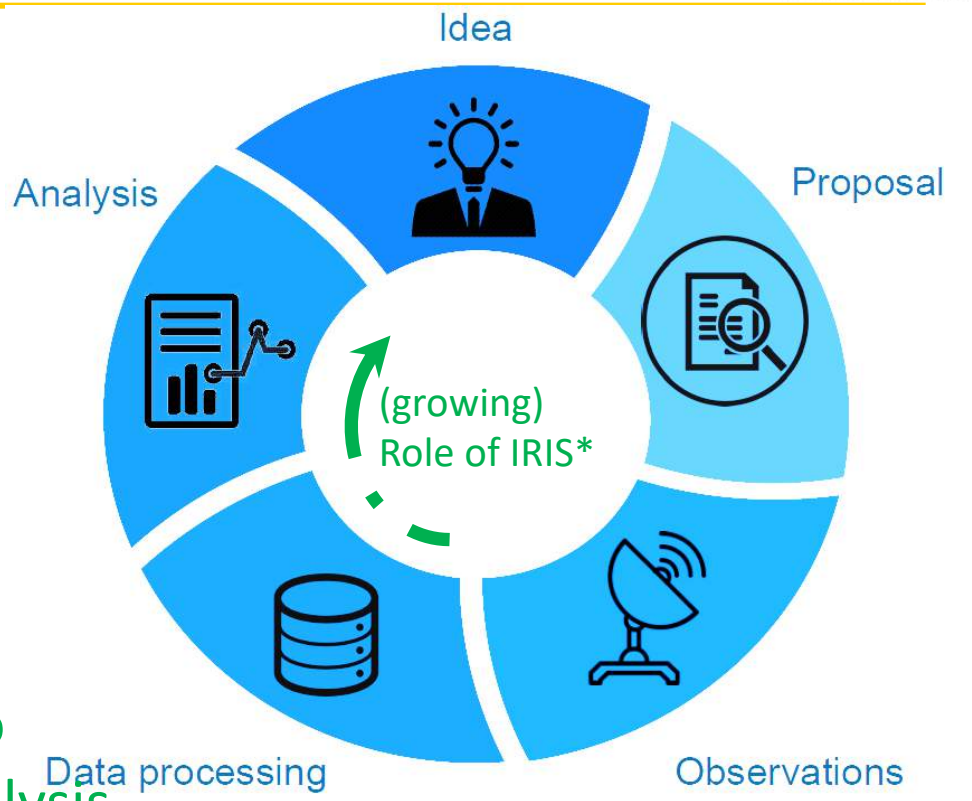
- Highly *international communities*

e.g. ~50% of e-MERLIN PIs/co-Is being from non-UK institutes

- Help offered (f2f, remote, online etc) at all stages
- Diverse mix of small teams and large programmes
- Experienced & new users

ALMA-UK - primarily UK ALMA users

e-MERLIN – support all users



Growing role of IRIS hardware to extend processing & science analysis capabilities – himem (TB-scale) key capability extension

* Plus future archive exploitation

Facility aim to 'reduce the accessibility bar' for users at <u>all stages</u>

Train, build, facilitate and assist user community

= more, and better, science

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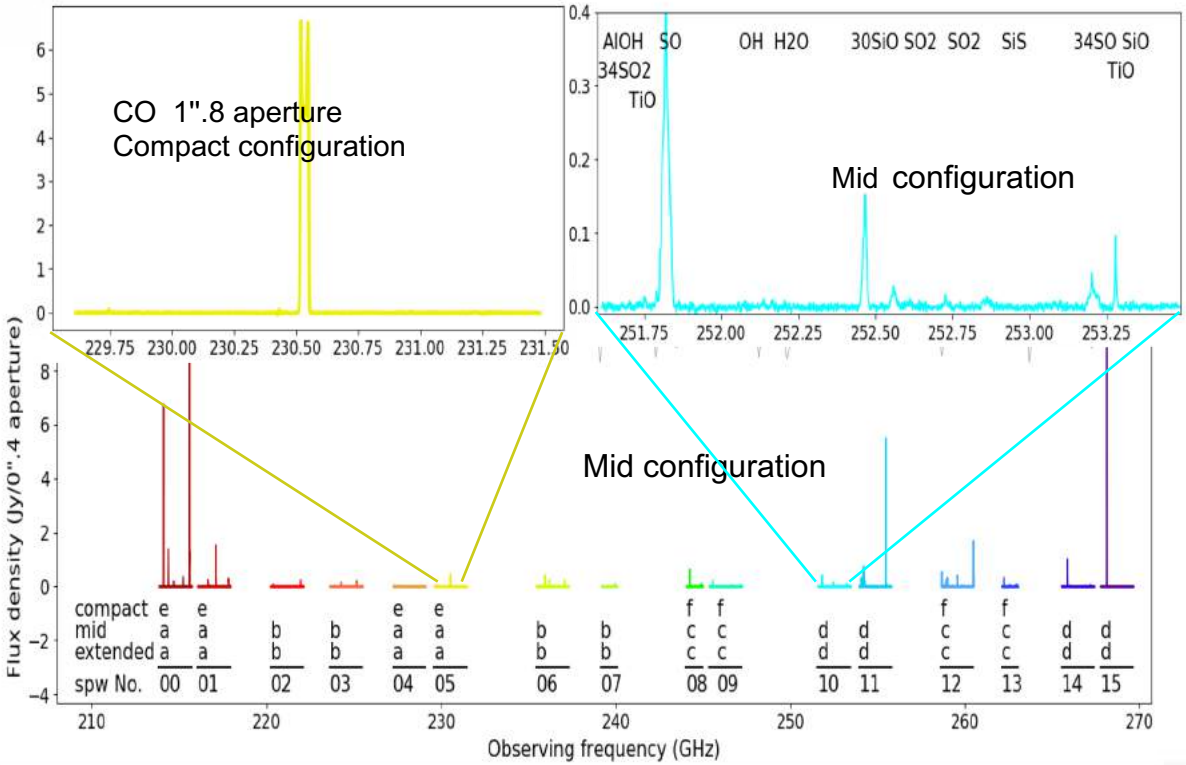
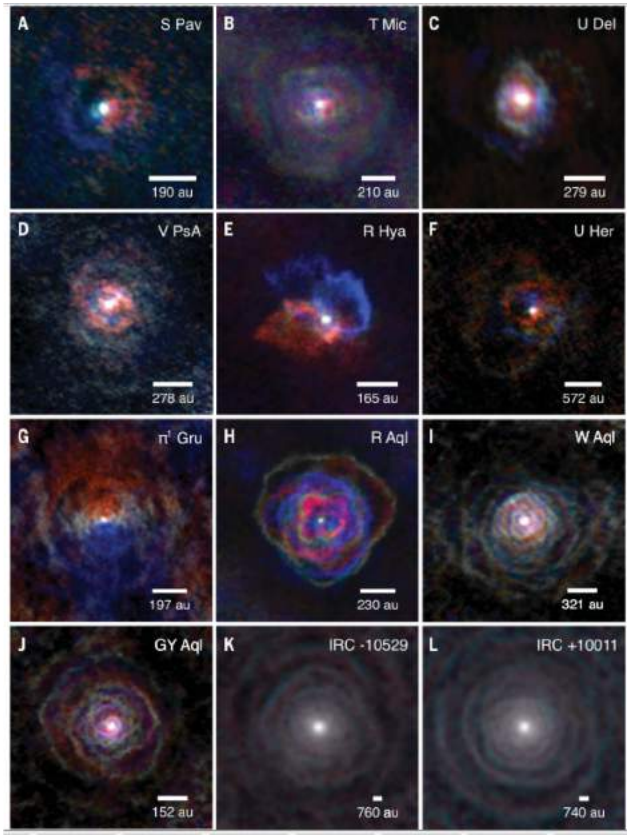
An example:
ATOMIUM* – An ALMA large programme

ALMA large program – 120hrs observing time, complex data structure, multiple arrays, many many spectral lines
ALMA-UK - main data reduction hub

*ALMA Tracing the Origins of Molecules In dUst-forming oxygen- rich M-type stars





Decin et al 2020, Science;
Horman+ 2020, A&A

ALMA-UK ARC – main data reduction hub for project.
Enabled by IRIS himem machines

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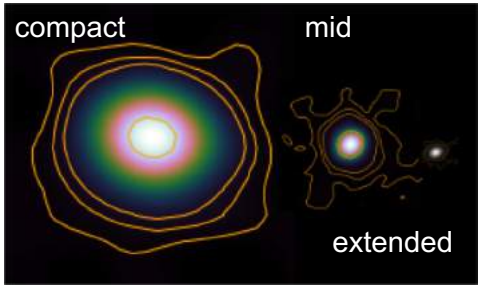
ATOMIUM Data Reduction on IRIS

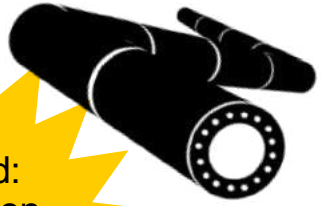
ALMA observatory/ESO
Pipeline calibration
Initial cubes

UK ARC, Manchester
IRIS computing
Atoms access by VPN

Self-calibrate continuum
Apply to all data



Understand:
Dust formation
Wind driving
Shaping
of CSEs
& PNe



Extract spectra
Line ID (CDMS)
Codes e.g. Hydro
Phantom, AMVAC
Chem e.g. KROME
Masers...

Line cubes for each config ~70,000 chans per star.
Over 1 million channels total

17 stars, 3 array spacings, 2 or 4 frequency tunings = 482 data sets - 48 TB
Current result is 200 GB per data set, will be final product of 3 TB per star
Memory intensive imaging, along with manual masking

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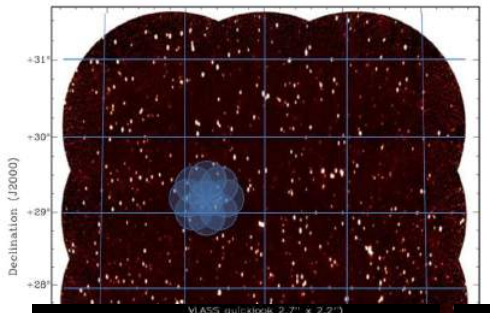
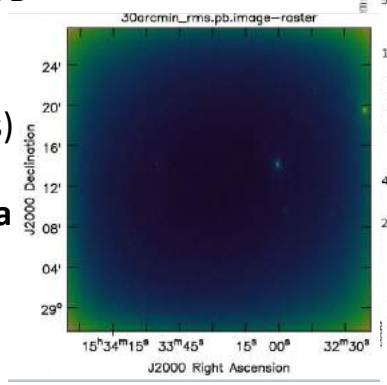
e-MERLIN – wide-field imaging for key programs

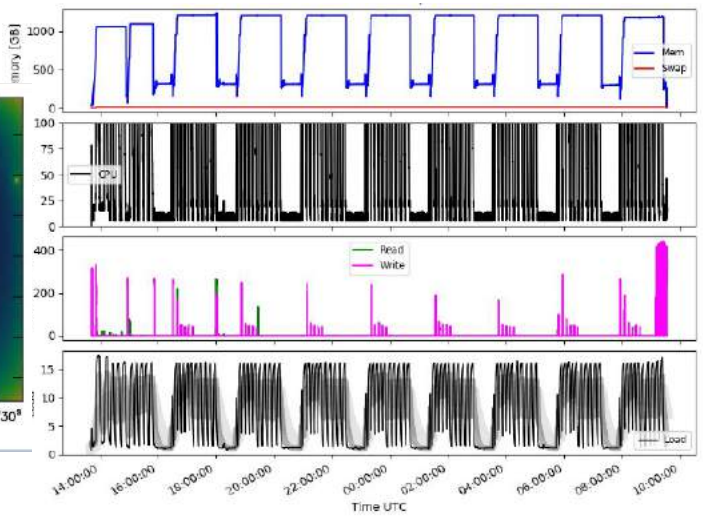
- Essential any large key program e.g. e-MERGE, SuperCLASS, COBRAS (100-1000s hr projects, few to 10s TB datasets)
- Need enough RAM to hold several 45k+x45k+ 2D FITS images in memory plus as much input data as possible.
- Paramaterising GPU implementation
- e-MERGE (DR1 25% of data) required 1.5TB RAM to image, DR2 (100% data, 4 times area) will scale to ~3TB *(Muxlow et al 2020, MNRAS)*

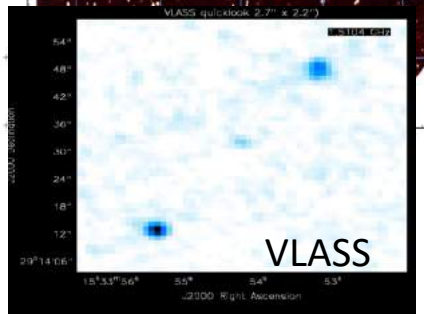


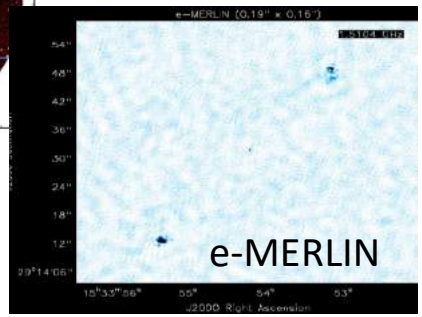
5 runs on pointing ~0.8TB

45,000 pixel image
10µJy/bm (188x170mas)
(Bigger image than the standard SKA1-mid data products)









Memory usage driven by image size –
all e-MERLIN programs can image full FoV.
Currently only done in selected cases.

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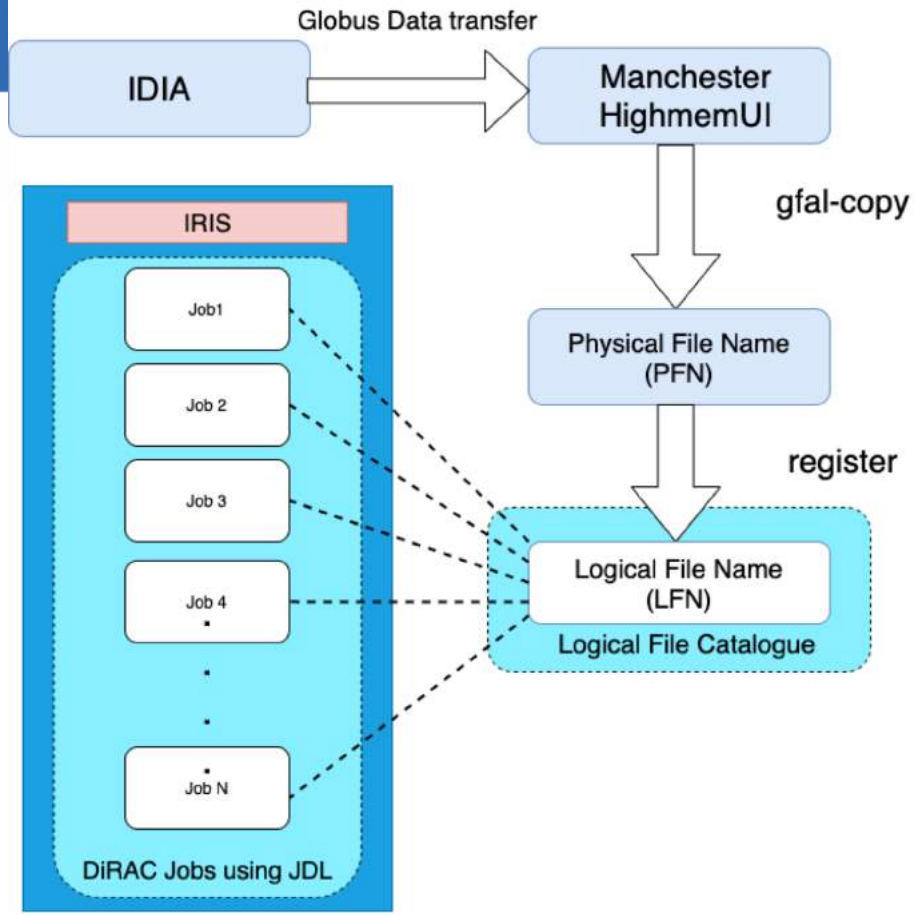
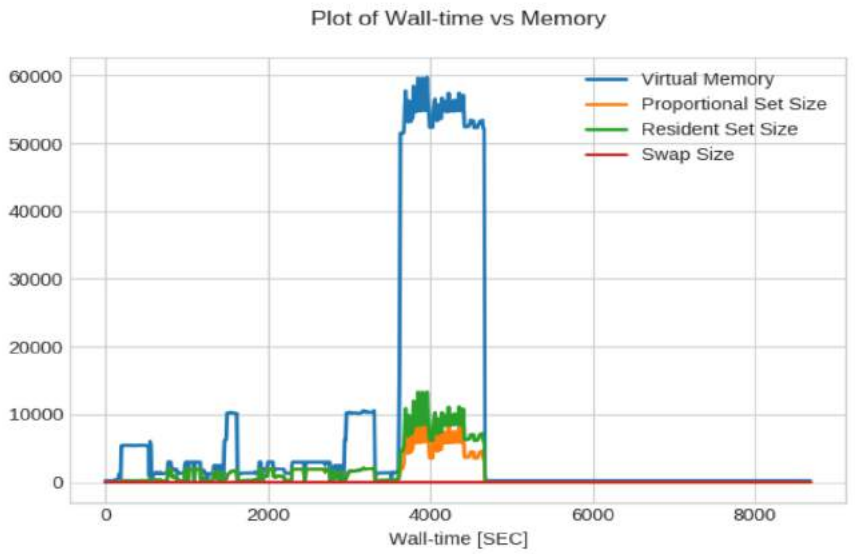
Delivering workflows for SKA pathfinders & precursors

MeerKAT, jVLA, LOFAR .. processing -



https://idia-pipelines.github.io/docs/processMeerKAT/calibration-in-processmeerkat/

- Data are transferred using Globus end points in Cape Town and Manchester (takes ~12 hours per ~1TB dataset)
- Originally tried adding directly to the DIRAC filecatalog using a UI in Cape Town, but the transfer was very slow (3 days for a single dataset).
- Process now Globus followed by local registration using the DIRAC file catalog client.
- Intention to write stand alone DIRAC task for register-in-place
- Himem load at imaging stages, testing and optimisation



Small MeerKAT data set – himem imaging stages

Some of the next stages…

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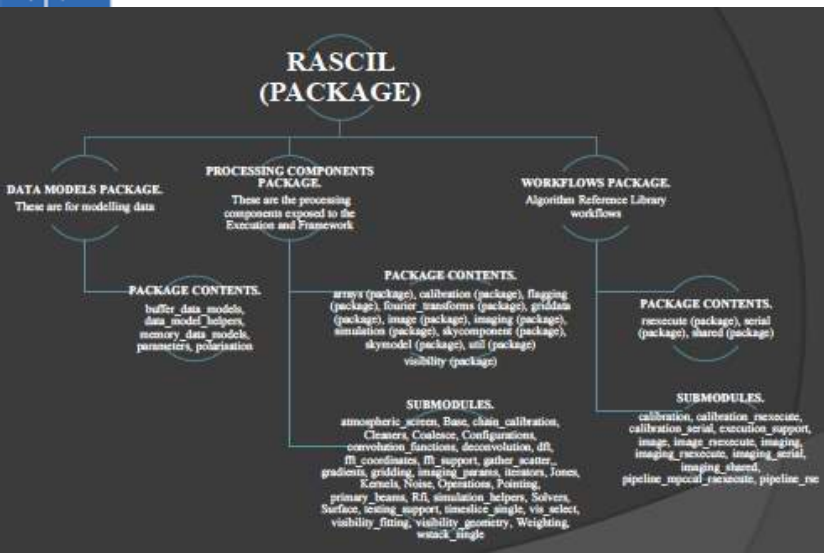
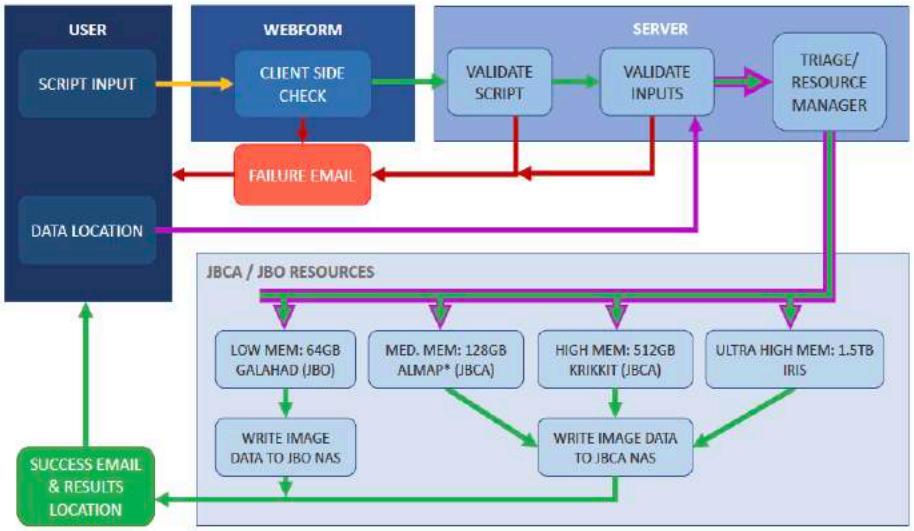
Developing, extending and expanding services:



e-MERLIN as a test-bed for new SKA science data processor (SDP) software
RASCIL – Radio Astronomy Simulation, Calibration and Imaging Library (Cornwell).

- RASCIL testing and development on IRIS nodes using data from multiple facilities (inc. e-MERLIN, ALMA, jVLA, MeerKAT, LOFAR etc)
- Early delivery (and acclimatisation!) to users (e.g. e-MERLIN), via implementation in parallel to existing 'traditional' pipelines



Joint e-MERLIN/ALMA service developments:
New access platform to open access to users, irrespective of team experience or expertise

- Aim to - Reduce 'access/entry'-barriers
- Bases on extendable containerized approach
- Reproducibility
- Efficient resource management allocation, access validation
- Access to run 'parallel' processes (e.g. different work flow, realisations)
- new s/w vs 'trusted' s/w (e.g. RASCIL vs CASA) (community adoption/acclimatisation)

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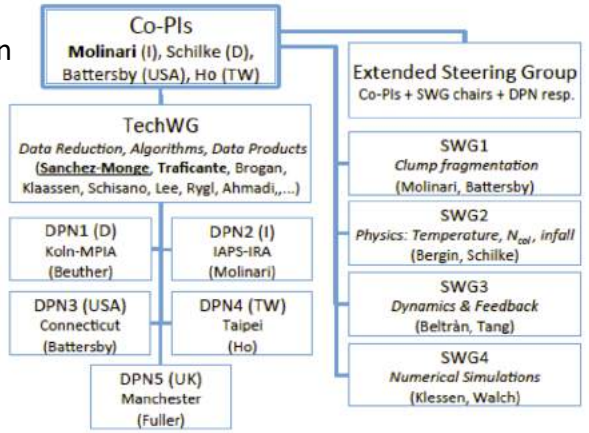
Extending support ALMAGAL:
ALMA Evolutionary study of High Mass Protocluster Formation in the Galaxy

The ALMA Large Program 'ALMAGAL' is targeting 1000 dense high-mass star forming clumps in the Milky-way at a wavelength of 1mm. ALMAGAL will answer fundamental questions on the physics responsible for the fragmentation of molecular clumps into star forming cores. The products of ALMAGAL will provide a significant legacy resource for the star-formation community.

The program uses 3 ALMA array configurations covering a range of spatial scales and ultimately providing 1000AU (0.2") resolution.

The sample size requires the use of the computationally demanding auto-masking when cleaning/imaging the data. A fraction of the sample are candidates for self-calibration which will demand additional processing once identified.

The UK ARC Node is identified as one of five data processing nodes in the project.



ALMAGAL data processing requirements:

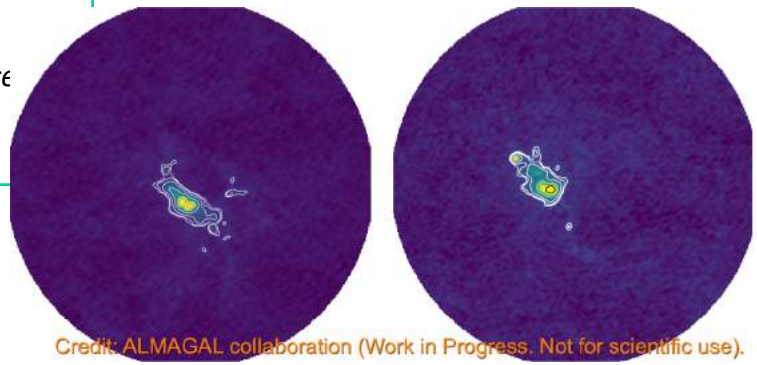
Spectral

- 3 ALMA Arrays per source over 4 SPW = 12 x 4 giga-pixel* cubes
- +1 x 4 SPW combined data cubes (same pixel size) -> *approx. 40hr per source***
- Plus the same again for continuum subtracted cubes.

Continuum

- 3 x 2 SPW continuum images = 6 x 1 mega-pixel images
- +1 x 2 SPW combinded data image (same pixel size) -> *approx. few hrs per source*

A total of 300-400TB. Plus additional products for sources which are self-calibrated.



- Cube dimensions = 1024x1024x3840 pix : Continuum images = 1024*1024 pix.
- **Cube time estimates by comparison to ATOMIUM

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Extending services:
ALMA Archive Advanced Products (A3P)

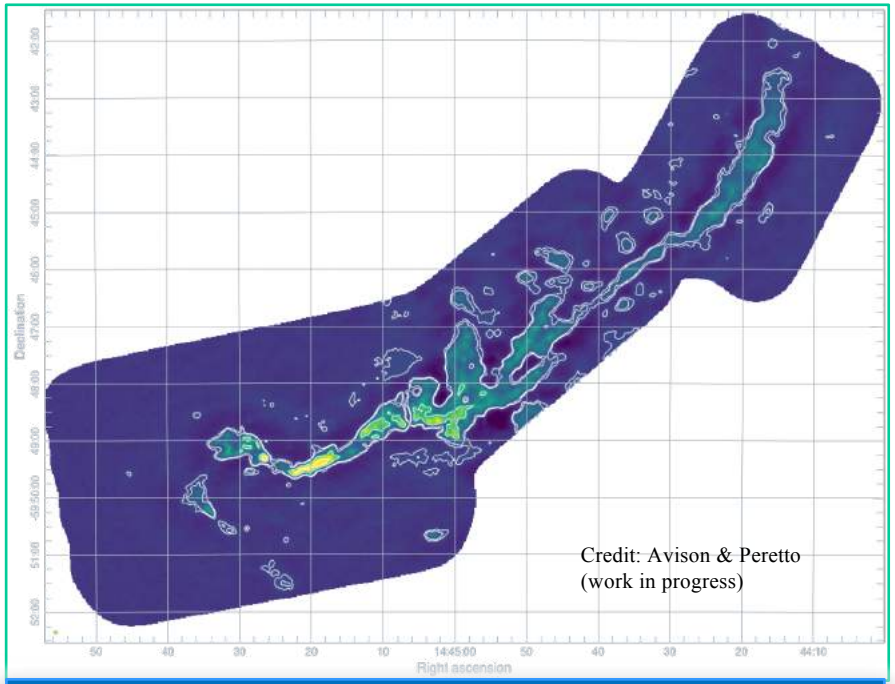
e-MERLIN

The UK ARC Node is involved, in collaboration with ESO, with the A3P initiative. A3P aims provide high quality, "advanced" products through the combination of complimentary datasets in the ALMA Archive.

Design study projects in A3P:

- ***Galactic Centre:*** Gather and combine/reimage all ALMA observations of regions within the central region of the Milky Way. *Requirements: Large scale mapping, multi-epoch dataset combination and processing.*
- ***Chemistry in protostellar disks:*** *Collect, combine and analyse the spectral data cubes for all protostellar disks observed by ALMA. Requirements: high spectral resolution imaging, cube wide spectral detection and analysis.*

Large scale mosaics, over multiple cubes and spectral line analysis over giga-pixel cubes are computationally heavy tasks.



ESO ALMA RC wide program

UK: Builds on archive development and science expertise
Utilise extended compute access (esp himem) and new access platform developments to interface with archives for new services

The community is thinking the same:

The UK ARC Node is already handling request from the community for large scale data combination using PI lead and Archival products, e.g. large mosaics from multiple ALMA projects. Example: IRDC-G316.75 (Image dimensions 16x12 arc minutes, 1750 x 1260 x 200 pixels).

The image to the right uses low frequency (90GHz) ALMA data. The processing requirements pushed the limits of standard ARC node machines (hours – days to generate). Automasking required exceeded standard processing machine capabilities.
Creating an equiavalent image at higher frequency will require use of IRIS machines (or months-years otherwise).

www.alma.ac.uk
Email: alma-contact@jb.man.ac.uk

www.e-merlin.ac.uk
Twitter: @eMERLINarray
Email: emerlin@jb.man.ac.uk

www.jodrellbank.manchester.ac.uk

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