Getting ready for ASKAP Science

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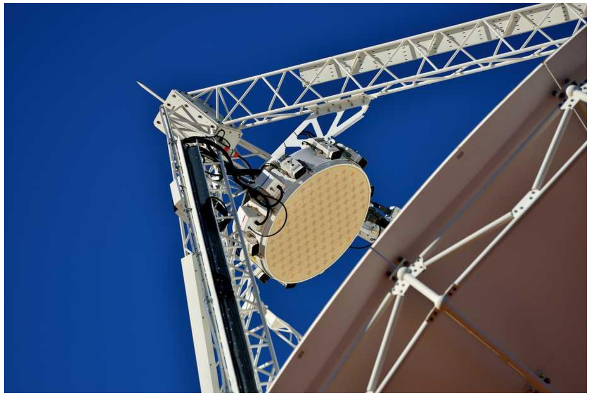
The Australian SKA Pathfinder (ASKAP)

- **Telescope layout**
  - Location: Murchison Radio-astronomy Observatory (WA)
  - 36 antennas, 12m diameter
  - Frequency range: 0.7 - 1.8 GHz
  - 300 MHz bandwidth
  - 16384 channels
  - Max baseline: 6 km
- **Antenna design**
  - Prime focus phased array feeds (PAFs)
  - 3-axis mount to track offset beams
  - 36 beams, 30 square degree FoV
- **Status**
  - Fully operating since March 2019
  - Currently completing the Early Science Phase (ESP)



ASKAP: a survey machine

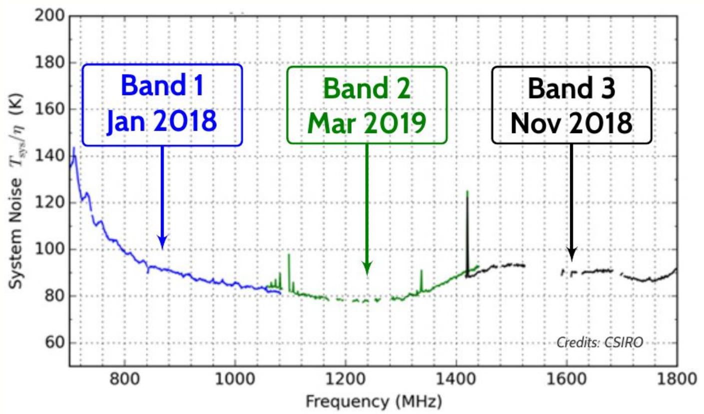
- **Unprecedented survey speed thanks to PAF large FoV**
  - Continuum: ~200 deg^2/hr @ 100 μJy sensitivity, 10” resolution, bw=300 MHz
  - Spectral-line: ~184 deg^2/hr @ 5 mJy sensitivity, 10” resolution, bw=100 kHz

- **At least 75% of observing time allocated to surveys during the first 5 yr:**
  - EMU: all-sky, continuum
  - WALLABY: extragalactic H I emission
  - FLASH: extragalactic H I absorption
  - VAST: variables and slow transients
  - GASKAP: Galactic and Magellanic H and OH spectral lines
  - POSSUM: polarization
  - CRAFT: commensal fast transients
  - DINGO: evolution of neutral H in local universe
  - COAST: pulsars
  - VLBI in combination with the Australian Long Baseline Array

- **5-year observing plans need to be tested and verified in advance!**
  - Early Science Program (ESP)
  - Pilot surveys

ASKAP Early Science Program (ESP)

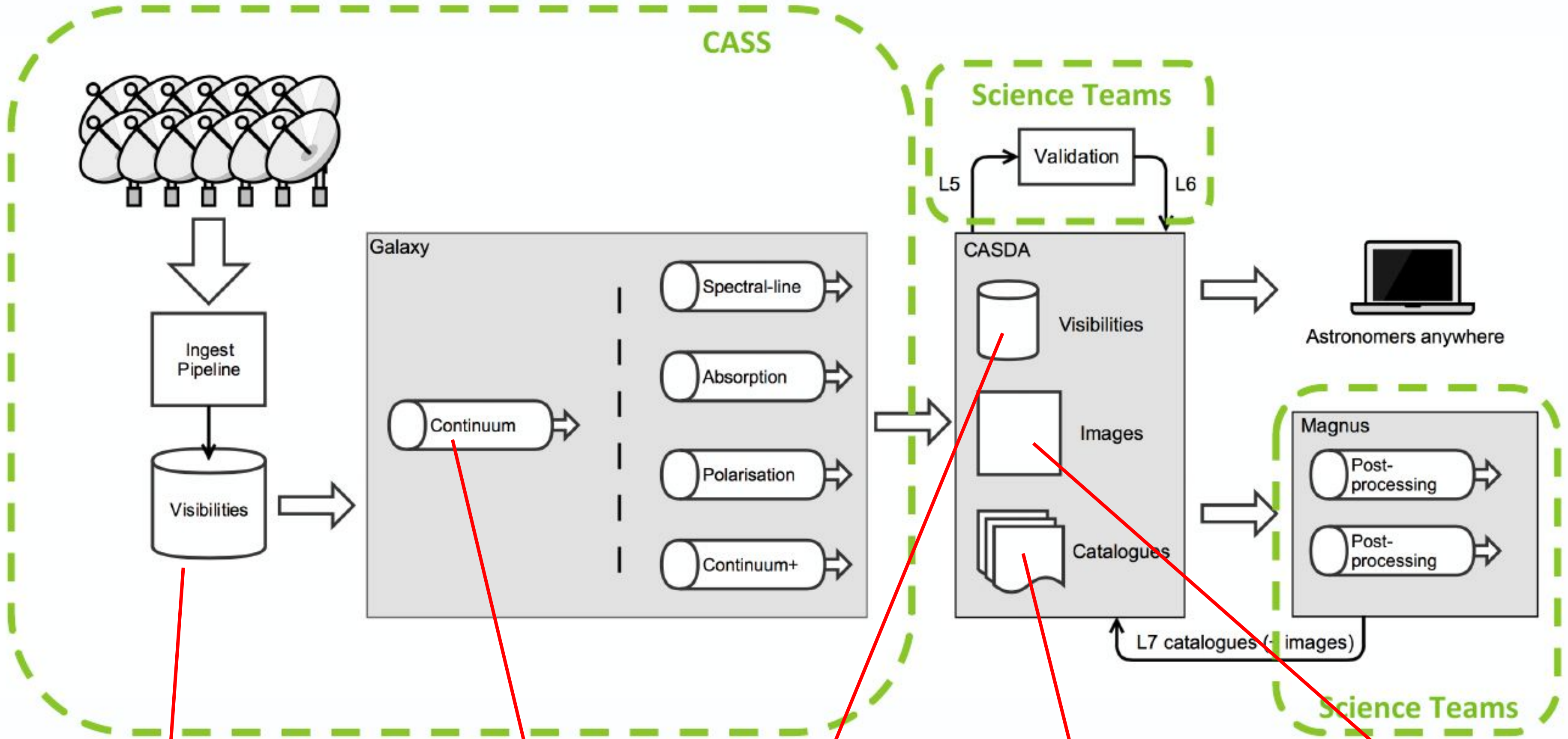
- Started in October 2017
- Several target fields observed during the array commissioning at different frequencies
  - ➢ Data processing still ongoing for some of them
- Main objectives are validation of:
  - ➢ Array operations and observation strategy
  - ➢ Data reduction pipeline & computing infrastructure (Pawsee Galaxy)
  - ➢ Development & testing of post-processing algorithms



- We can do science with ESP data! --> several papers already published

  → https://www.atnf.csiro.au/projects/askap/askap-publications.html
- INAF involvement in ESP in the context of ASKAP EMU survey
  - ➢ **ESP7**: RQ-AGN - A pilot study in the GAMA survey fields (PI: I. Prandoni)
  - ➢ **ESP10**: A wideband image of the SCORPIO survey region (PI: C. Trigilio)
  - ➢ **ESP20**: Radio Emission in the Shapley Concentration: from galaxies to cluster and intracluster scale radio emission (PI: T. Venturi)

ASKAP Early Science Pipeline



~40 TB per SB (36 antennas, 36 beams, ~11 hrs obs., ~16000 chan)
1 ESP Project has multiple SBs

~1 TB per SB after averaging to 288 chans

~25 GB per beam (288 chan)

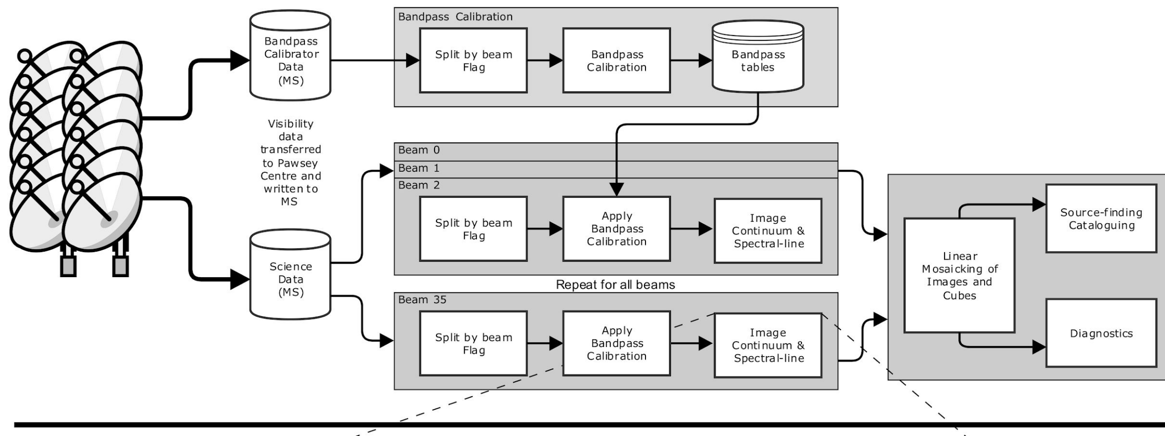
~10 MB per map (~40 deg^2 field)

~300 MB per map (~40 deg^2 field)

ASKAP Early Science Pipeline

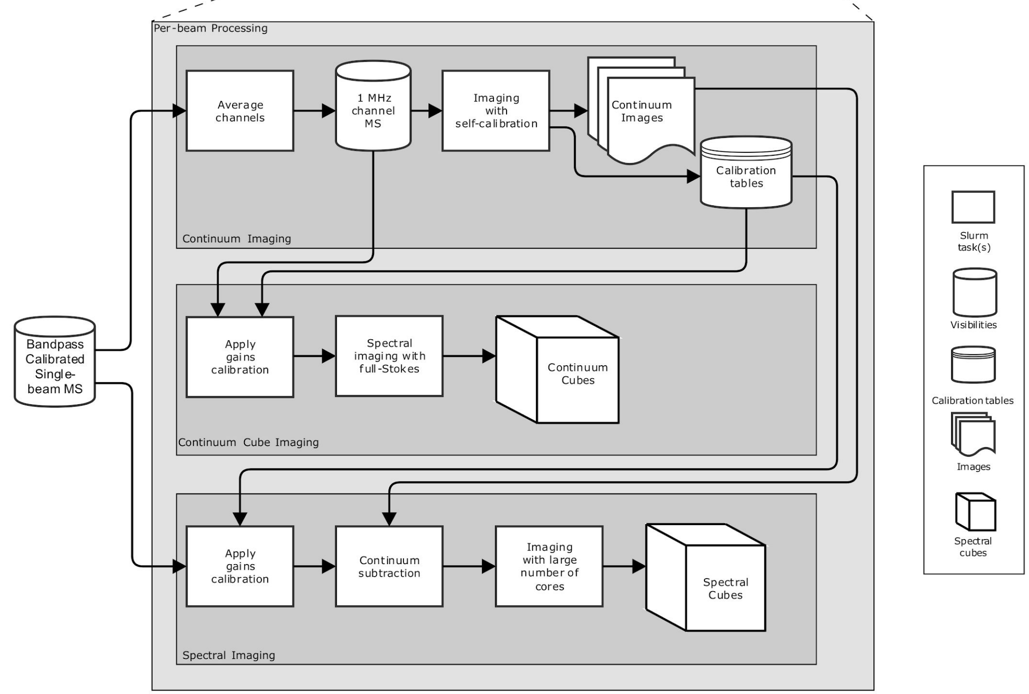
ASKAPSoft science data processing:

- a series of parallel and mutually dependent Slurm jobs running on the Galaxy HPC system
- Processing for a beam is mostly independent from other beams



Typical resources used:

- ~241 cores/beam
  - 1 core/beam for simple tasks (data copying, BPCAL splitting/flagging and applying calibration solution, band averaging, mosaicing)
  - 216 cores/beam for find bandpass
  - 241 cores/beam for self-calibration and imaging
  - 19 cores for source finding
- ~2.5 GB peak virtual memory per core (in continuum imaging tasks)



The Scorpio ASKAP ESP Project

First blind survey of the Galactic plane at this frequency with a planned sensitivity of 30 μJy/beam.

Scientific goals:

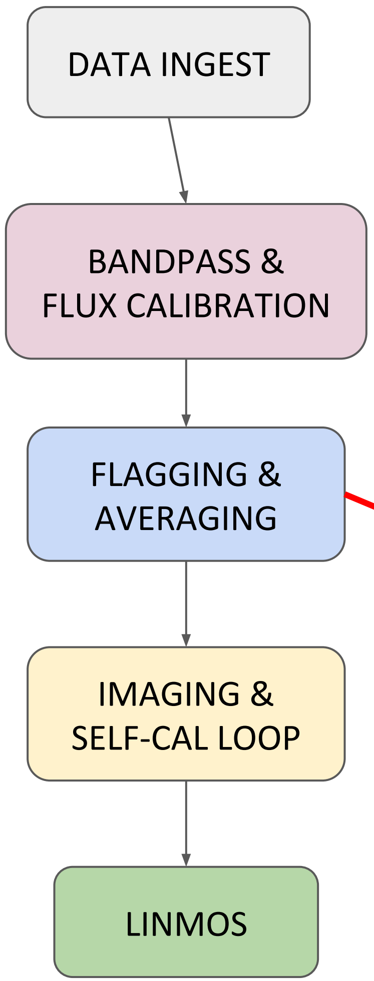
- unbiased search for radio stellar emission
- insights on the physics of particular classes of stellar systems
- search for coherent radio emission from stellar systems
- study the occurrence of different Galactic objects (e.g. PNs, HIIs, SNR)
- provide us with a clear forecast on the potential of SKA and its precursors in the field of Galactic radio astronomy

Technical goals:

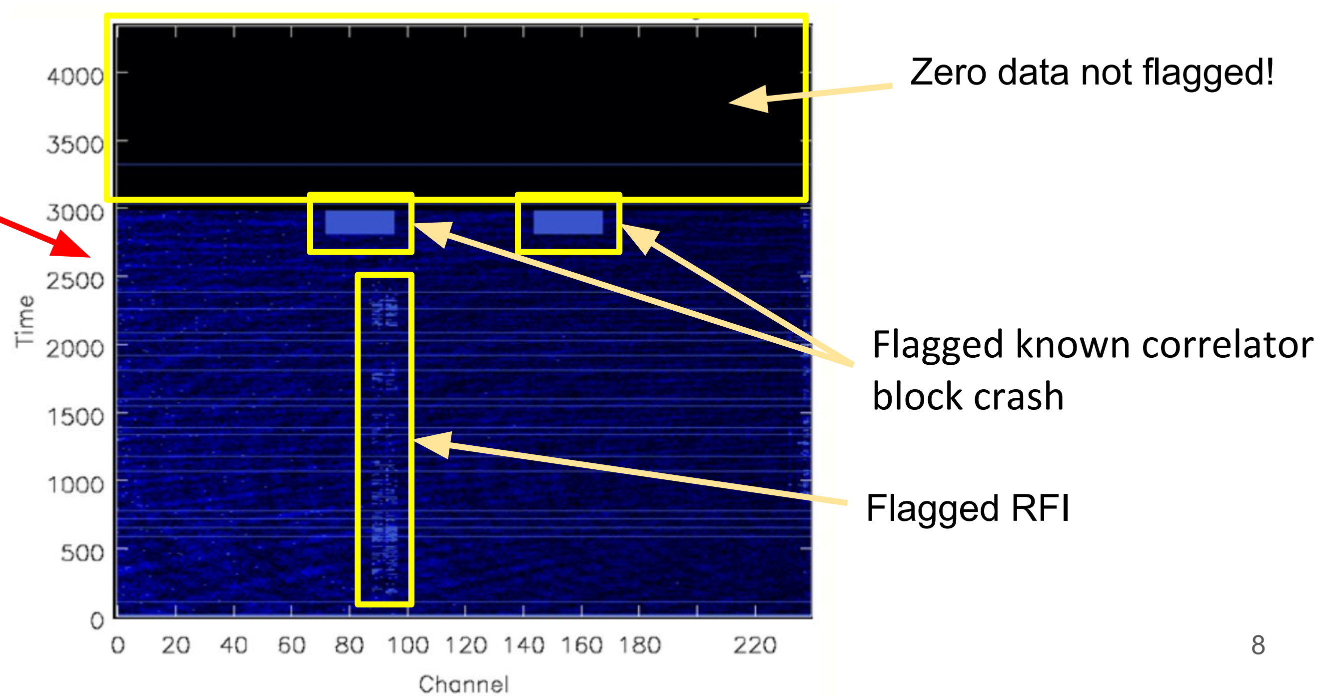
- Test of ASKAP pipeline on the Galactic plane (extended objects, diffuse emission, ...)
- Development of imaging and analysis techniques suited for the Galactic plane

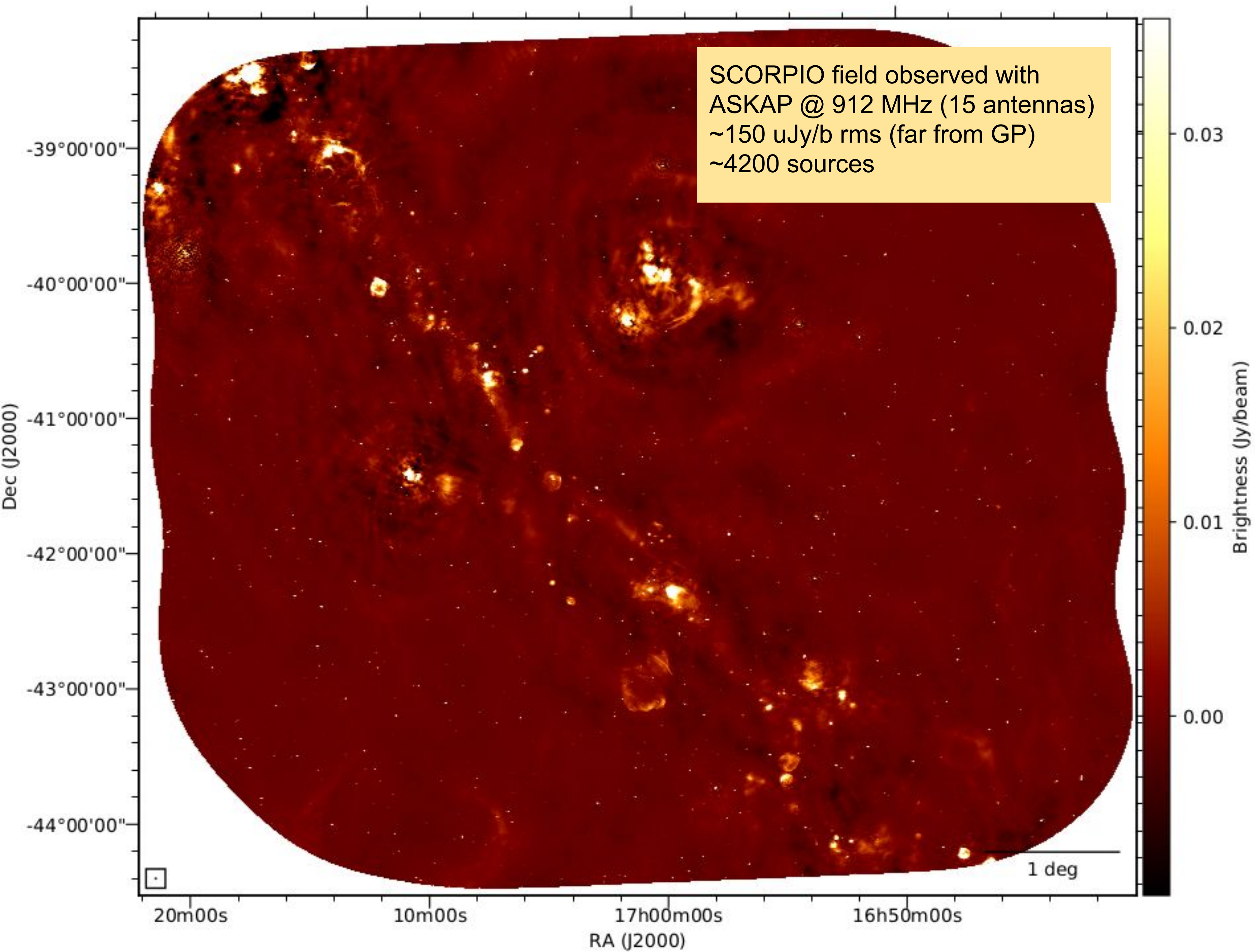
SCORPIO data reduction & issues

Tweaking ASKAPsoft pipeline for Galactic data...

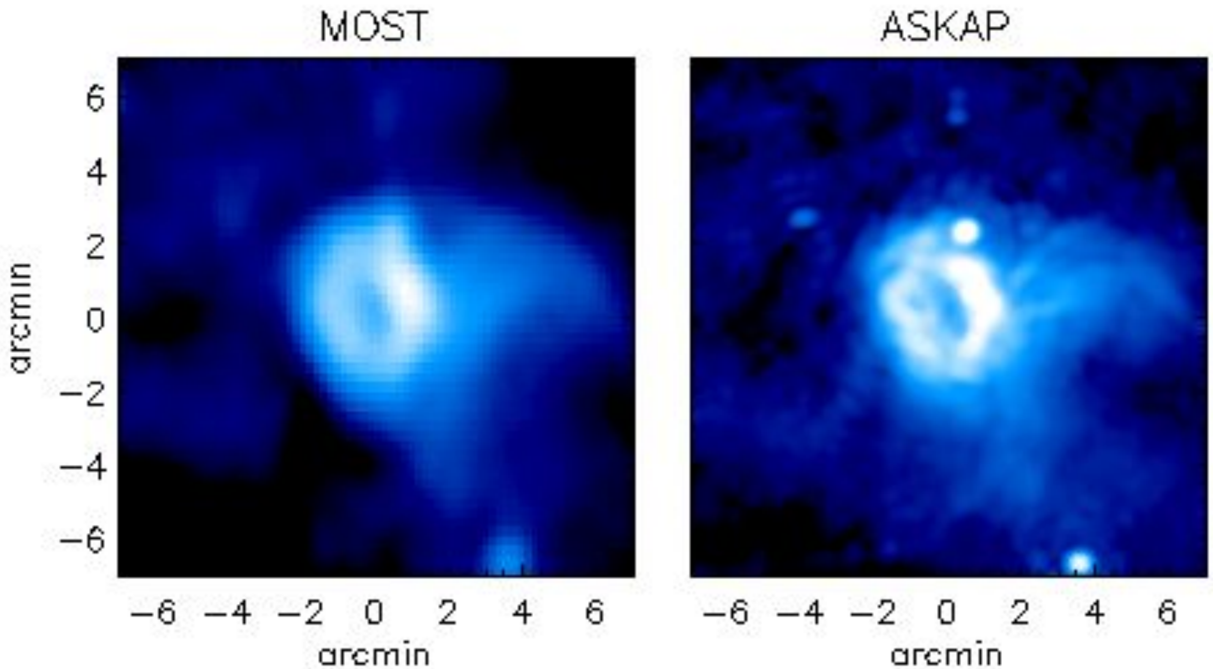


- User congestion, job failures (scratch space filling up, long queuing times, timeouts, ...). Mostly solved by centralizing data reduction
- Some bad data not flagged (using default flagger parameters)
- Excluding short baselines from self-cal due to extended sources

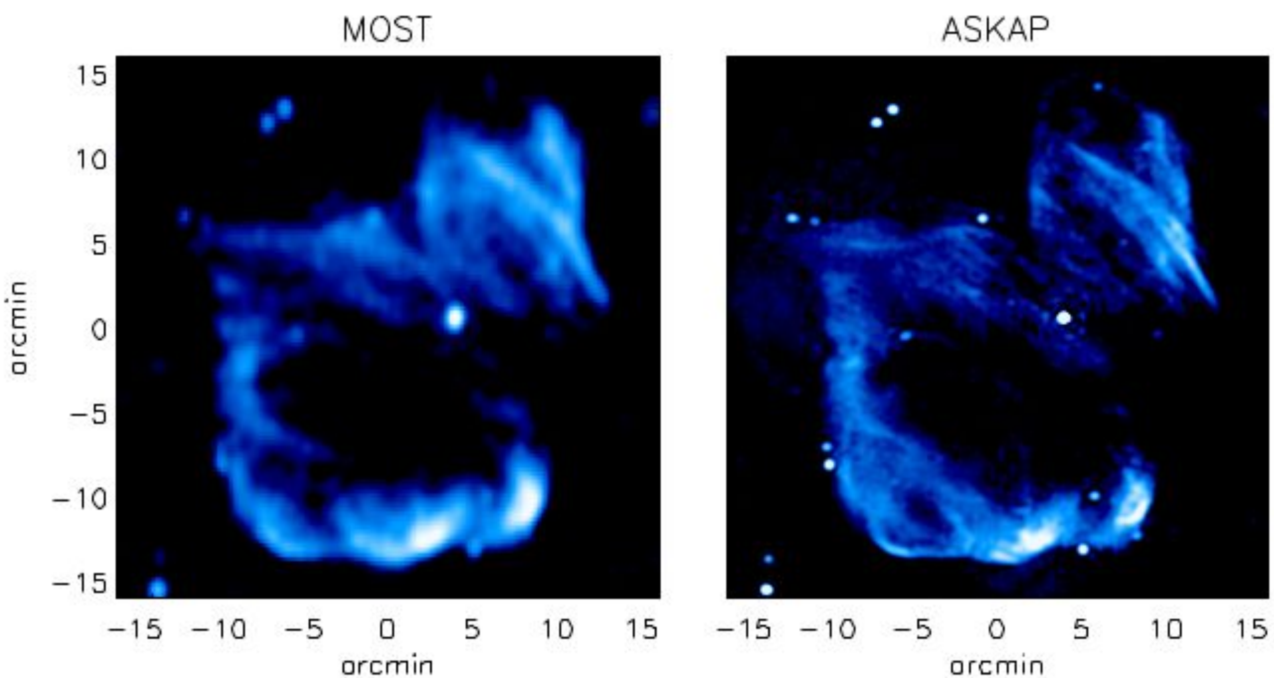




SCORPIO field observed with
ASKAP @ 912 MHz (15 antennas)
~150 uJy/b rms (far from GP)
~4200 sources
-39°00'00"
-40°00'00"
-41°00'00"
-42°00'00"
-43°00'00"
-44°00'00"
Dec (J2000)
20m00s
10m00s
17h00m00s
16h50m00s
RA (J2000)
1 deg
0.03
0.02
0.01
0.00
Brightness (Jy/beam)



S17 HII region observed with MOST (left) and ASKAP (right)



G343.1-0.7 SNR observed with MOST (left) and ASKAP (right)

Results & lessons learnt from SCORPIO ESP

Several lessons learnt:

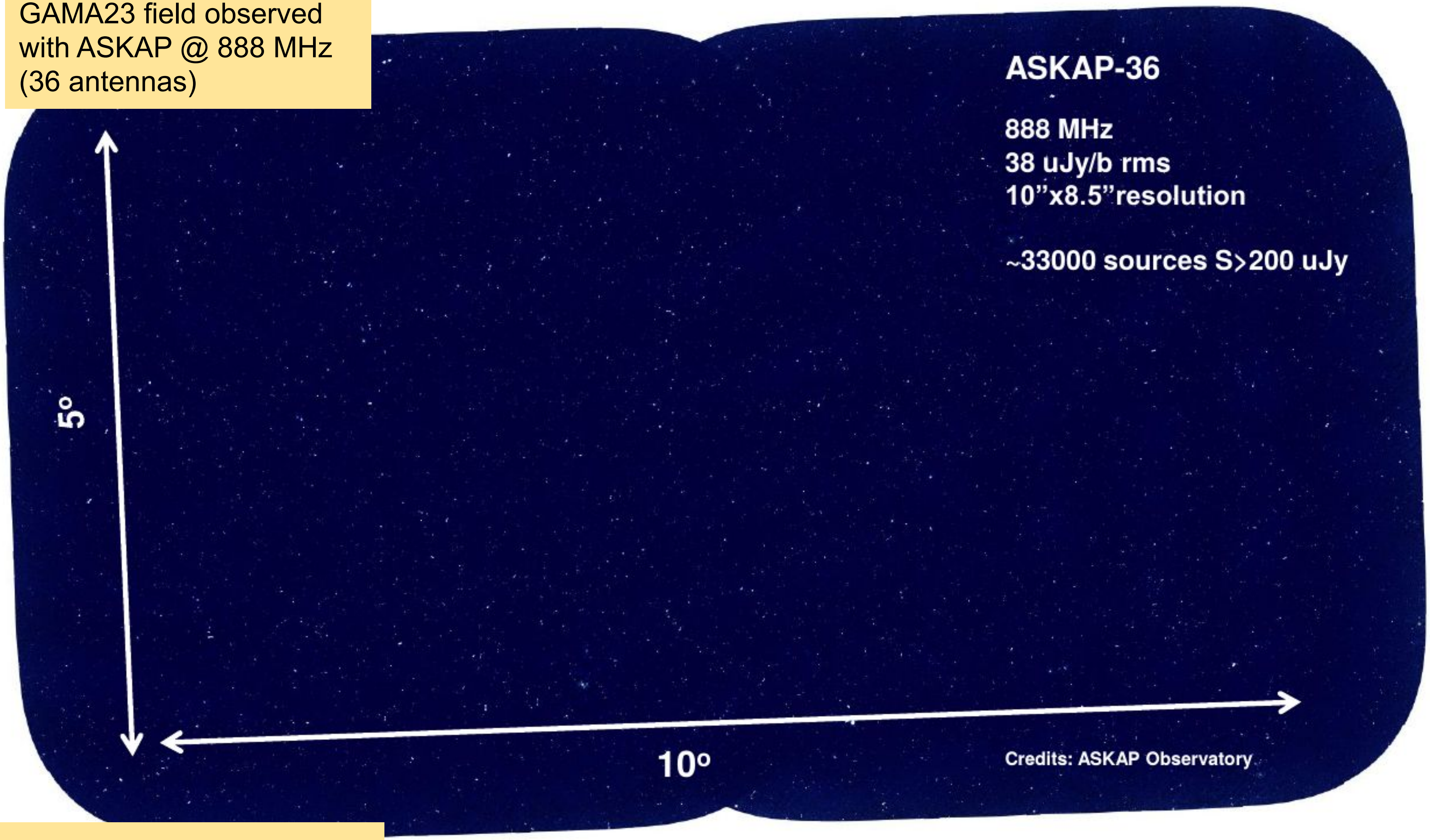
- Optimization of pipeline parameters for Galactic fields
- Improvements and testing of CAESAR source finder performances for both compact and extended sources (e.g. S. Riggi et al, PASA 2019)
- Development of post-processing algorithms for value-added catalogue (spectral indices, cross-matches, classification, etc) under way

Scientific results (even with an incomplete array!)

- Presentation and validation of ASKAP Scorpio data (Umana+ in prep)
- Compact source extraction and catalogue (Riggi+ in prep.)
- Characterization of PNs (in collaboration with WSU)
- SNR characterization and new discoveries (Bufano+ in prep.)
- Characterization of HII regions (Ingallinera+ in prep.)
- Multiwavelength studies of SCORPIO and synergies with CTA

Results & lessons learnt from EMU RQ AGN ESP

GAMA23 field observed with ASKAP @ 888 MHz (36 antennas)



Slide courtesy of I. Prandoni

Results & lessons learnt from EMU RQ AGN ESP

Several lessons learnt:

- Improved radio source catalogue with PyBDSF & Development of ASKAP-optimized forced photometry algorithms (Gurkan+ in prep.)
- Value-added multi-band catalogues (Driver+; Taylor+; Davies+ in prep.)
- Fine-tuning of AGN classification algorithms based on WISE colors and optical (GAMA) spectroscopy (Marchetti+ in prep.; Leahy et al. in prep.)

Slide courtesy of I. Prandoni

Science-driven projects ongoing

PI	Title / Description	Data used	Co-I
I.Prandoni	The Radio – Gas kinematics Connection / Explore correlations between radio luminosity and OIII outflows for various RE AGN classes – study spectral index distribution and radio morphology with GLASS	AGN GAMA catalogue / GAMA line equivalent widths/ ASKAP catalogue and forced photometry / GLASS for spectral index and high resolution morphology/ stellar masses and SFRs (not mandatory)	L.Marchetti G.Gurkan
G. Gurkan	Constraining the evolution of the faint radio source population/ Paper presenting the PyBDSF radio catalogue, the derived source counts (total and sub-populations) and sub-population LFs. Comparison with existing evolutionary models (Wilman+08,10; Mancuso+17; Bonaldi+18).	ASKAP catalogue, GAMA+photometric catalogues, incl. photoz/ stellar masses and SFRs (not mandatory)	I.Prandoni P. Padovani D. Leahy
I. Wong	very low-z radio quiet AGN	in collaboration with GLASS data (Jonny Rogers, Minh etc) as well	G.Gurkan, L. Marchetti, I. Prandoni ++
L.Marchetti	Investigate the entire population of WISE (only) or WISE+optical selected AGN exploiting PyBDSF fluxes in the Radio or forced photometry where needed. How do they compare with the one selected in the Optical? is there an evolution with z of their physical properties or a relation with the environment ?	Multiwavelength Optical GAMA photometry + optical spectroscopy + WISE (all-wise & possibly unwise?) + PACS/SPIRE from HELP (or HATLAS ?) + physical quantities (SFR, stellar masses) + photoz (from GAMA or KiDS DR4) + PyBDSF catalogue & forced photometry on WISE position + Possibly using GLASS as well.	I.Prandoni G.Gurkan M.Vaccari D. Leahy P. Padovani
D. Leahy	Comparison of AGN diagnostics: IR with optical (BPT). How do AGN diagnostics compare for the radio quiet galaxies (WISE plus optical spectra)? How do the AGN diagnostics compare for the radio emitting subsample?	Optical GAMA spectral line catalog + WISE+ PyBDSF radio source catalog + GAMA stellar masses; may use forced photometry on GAMA galaxy positions to increase WISE and radio source sample size.	I.Prandoni

ASKAPSoft porting to other infrastructures

- **Motivations**
  - ➢ Re-use optimized reduction algorithms for SKA
  - ➢ ASKAP data (e.g. CASDA products) re-processing in European data centers
    - ✓ ASKAP now moved to a centralized data processing model with dedicated staff to reduce data for all projects
    - ✓ Pro: less congestions at Galaxy cluster as science groups no longer allowed to fully process ESP data
    - ✓ Cons: less control of pipeline parameters, interaction issues
- **ASKAPSoft porting issues**
  - ➢ Galaxy dependencies (e.g. Lustre filesystem), dependencies on private ASKAP software
  - ➢ Installation issues on some Linux distributions (e.g. Centos)
- **ASKAPSoft being refactored by CSIRO, INAF testing on Singularity containers**
  - ➢ Yandasoft project: https://github.com/ATNF/yandasoft
  - ➢ ASKAPSoft Singularity container: https://github.com/SKA-INAF/askapsoft-container
  - ➢ Yandasoft Singularity container: https://github.com/SKA-INAF/yandasoft-container
  - ➢ Different tasks being tested on SCORPIO data
    - Flagging (OK)
    - Self-cal (FAIL)
    - Source finding (OK)
    - Linmos (OK)

Summary

- **ASKAP completed and fully operational from March 2019**
- **Early Science Phase ongoing**
  - ➢ Several fields observed with the commissioned array
  - ➢ Opportunity for improving the observation & data reduction process
  - ➢ Scientific results obtained even with a incomplete array
- **Pilot observations with full array**
  - ➢ Final validation before commencing the multi-year observing campaign
  - ➢ Larger fields (e.g. 270 deg^2 in EMU) observed and already reduced
  - ➢ High-level pipeline (L7 products) to be implemented and tested on this data
- **ASKAP developed software**
  - ➢ New source finder tools implemented and made available to the radio community
  - ➢ ASKAPSoft being ported for other computing infrastructures