Calibration in the IDIA pipeline

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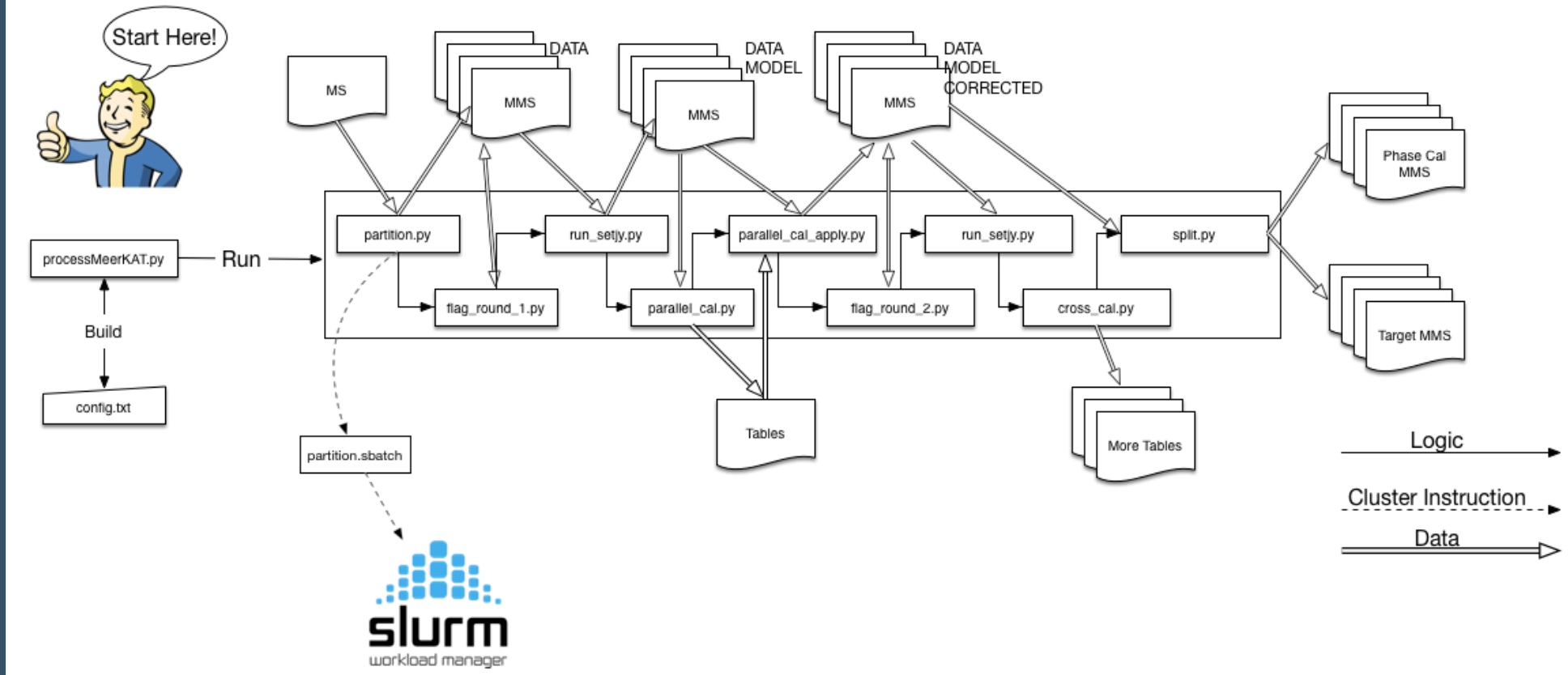
Brad Frank
Russ Taylor


Start Here!
MS
DATA
MMS
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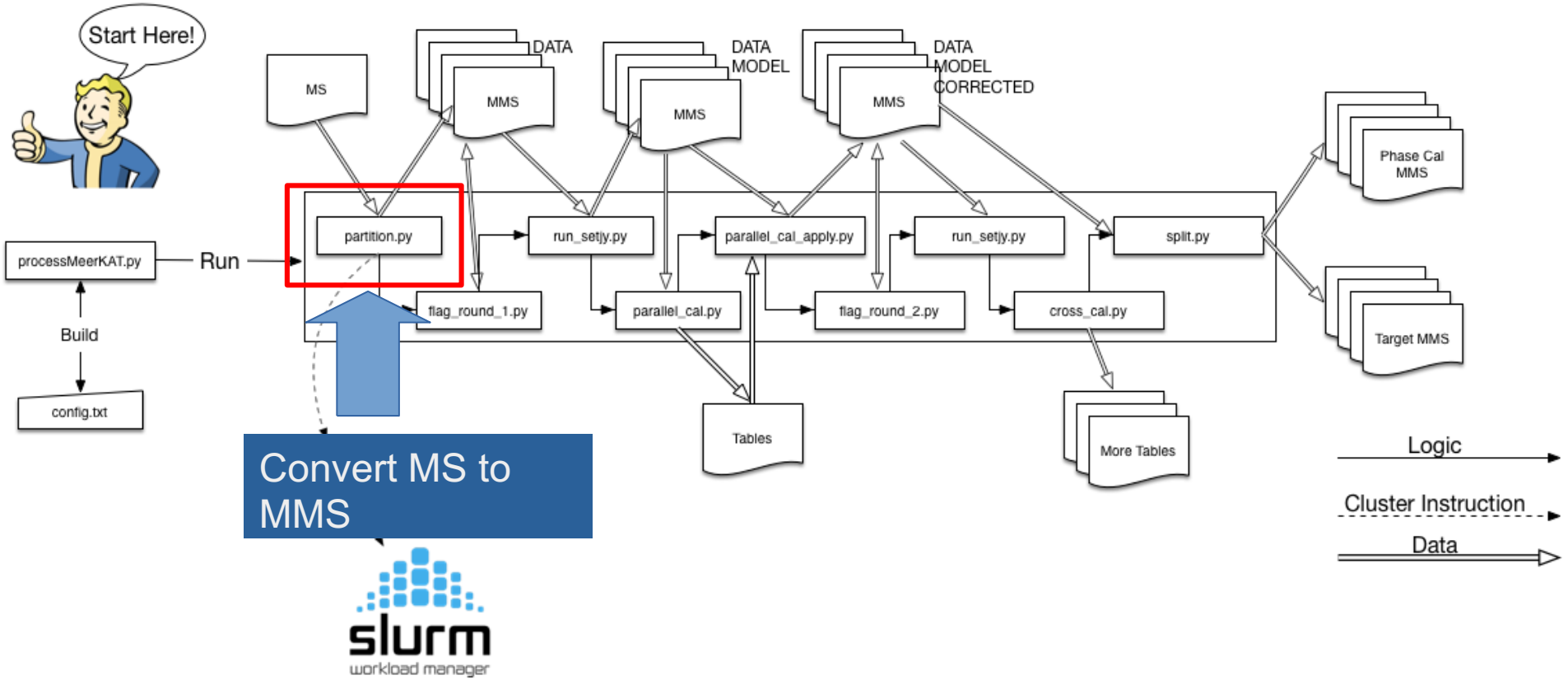
MODEL
CORRECTED
MMS
Phase Cal
MMS
processMeerKAT.py
Run
Build
config.txt
partition.py
run_setjy.py
parallel_cal_apply.py
run_setjy.py
split.py
flag_round_1.py
parallel_cal.py
flag_round_2.py
cross_cal.py
Target MMS
Tables
More Tables
partition.sbatch
slurm
workload manager
Logic
Cluster Instruction
Data

Pipeline goals

- Full Stokes calibration with the aim of producing continuum images/polarization cubes/spectral line cubes
  - (Full Stokes required for maximizing sensitivity in Stokes I)

Pipeline Philosophy

- Use multi-measurement sets (MMS) to parallelize across a cluster, take advantage of MPI aware tasks in CASA
- “Do the right thing” - Sensible defaults, get phases, fluxes, and polarizations right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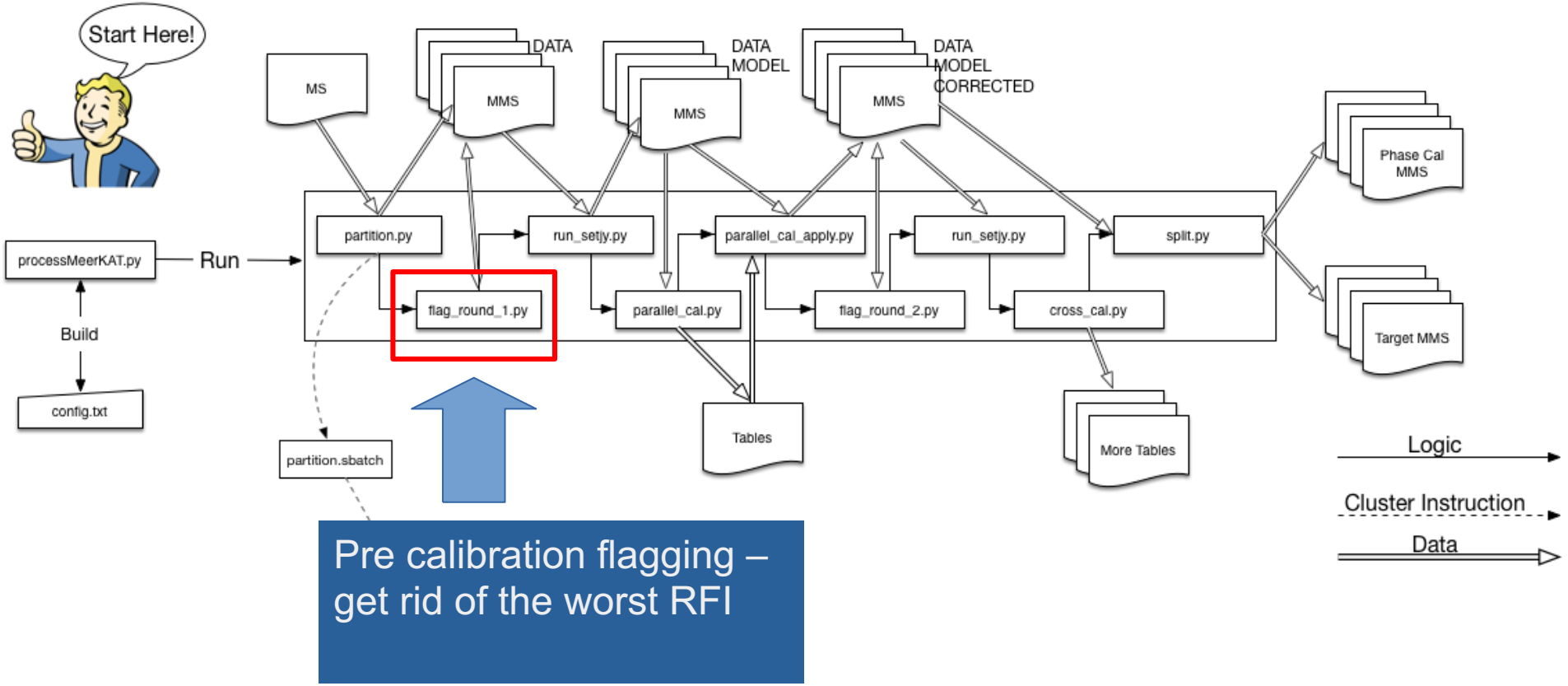
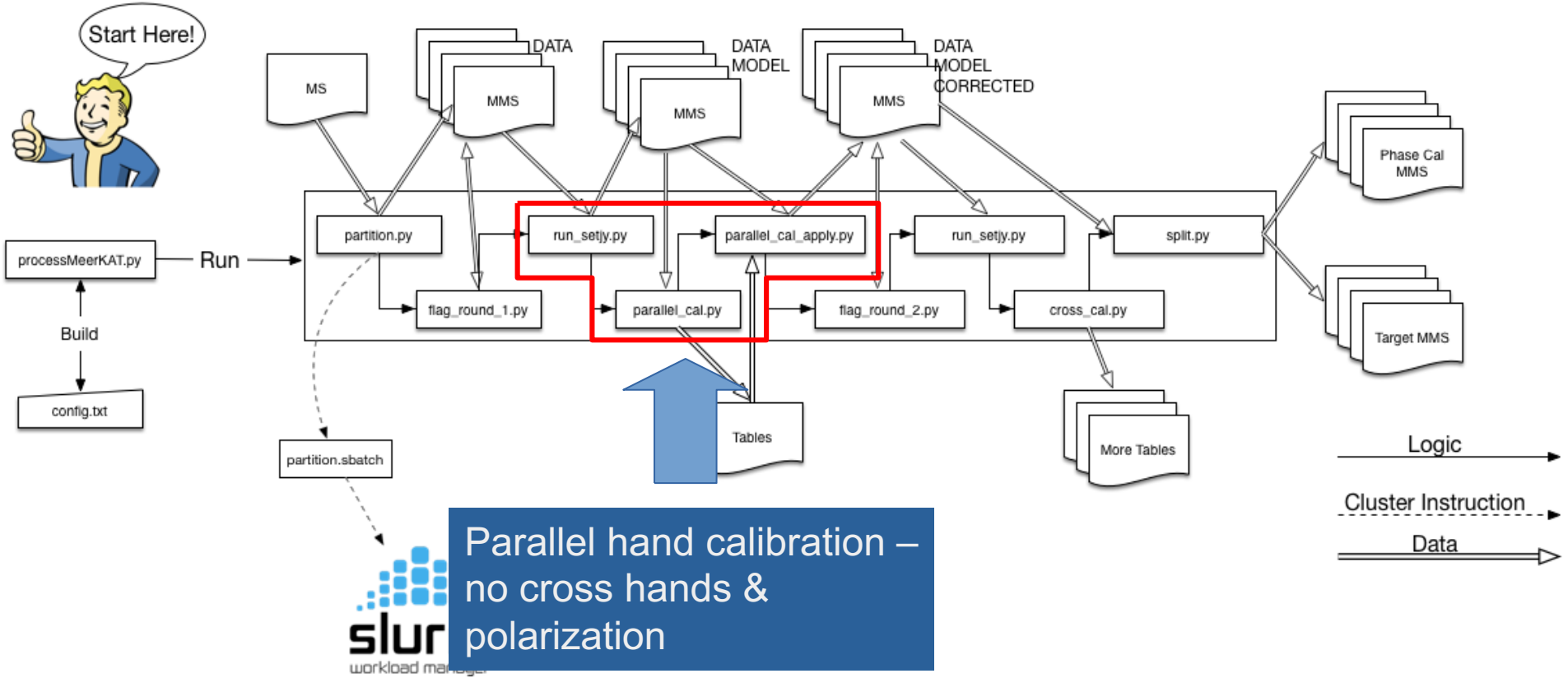


Pre calibration flagging – get rid of the worst RFI

Flagging

- Combination of clipping, tfcrop and rflag
- Set conservative limits while flagging pre-calibration
  - In principle tfcrop takes out the bandpass shape prior to flagging
- In general rflag more effective, particularly shorter baselines



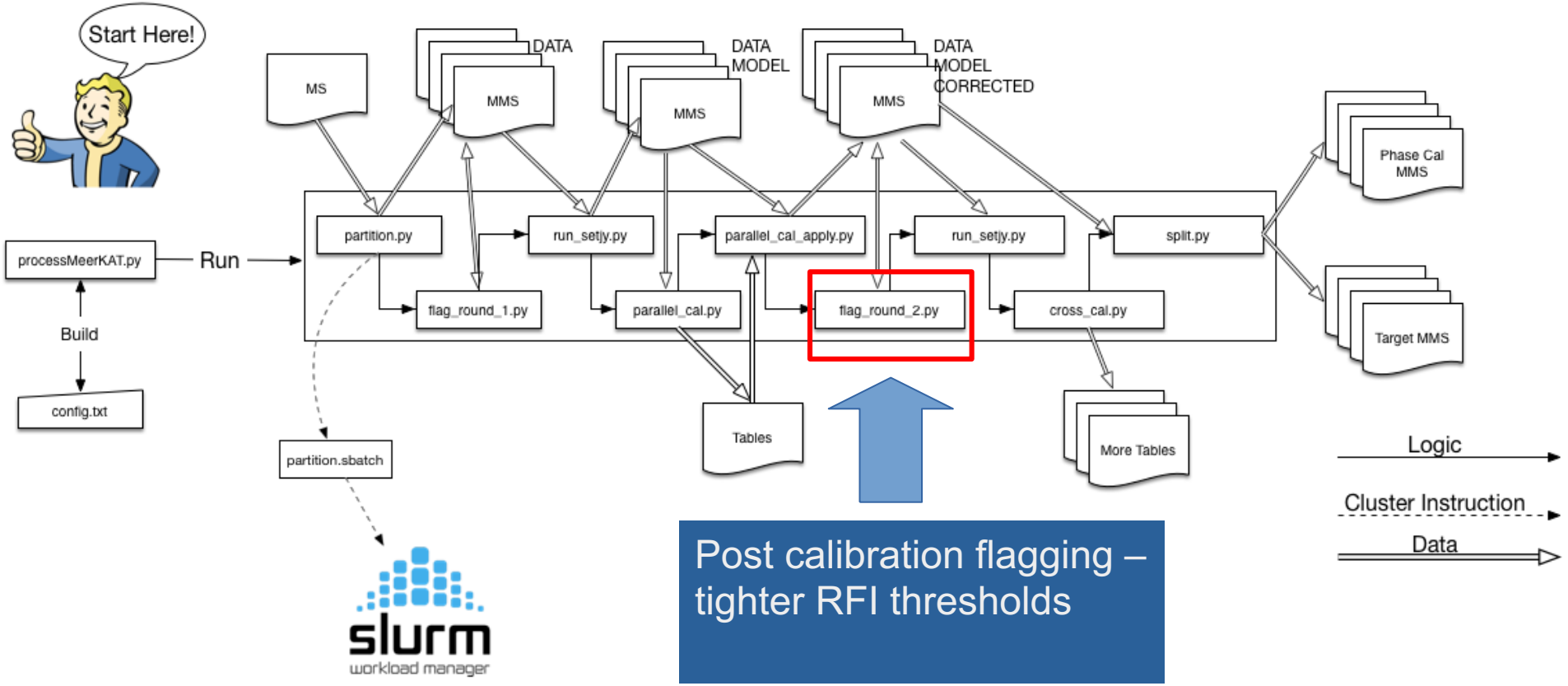
Parallel hand calibration – no cross hands & polarization

```
logger.info(" starting antenna-based delay (kcorr)\n → %s" % calfiles.kcorrfile)
gaincal(vis=visname, caltable = calfiles.kcorrfile, field
        = fields.kcorrfield, refant = referenceant,
        minblperant = minbaselines, solnorm = False,  gaintype = 'K',
        solint = 'inf', combine = '', parang = False, append = False)

logger.info(" starting bandpass → %s" % calfiles.bpassfile)
bandpass(vis=visname, caltable = calfiles.bpassfile,
        field = fields.bpassfield, refant = referenceant,
        minblperant = minbaselines, solnorm = True,  solint = 'inf',
        combine = 'scan', bandtype = 'B', fillgaps = 8,
        gaintable = calfiles.kcorrfile, gainfield = fields.kcorrfield,
        parang = False, append = False)

logger.info(" starting gain calibration\n → %s" % calfiles.gainfile)
gaincal(vis=visname, caltable = calfiles.gainfile,
        field = fields.gainfields, refant = referenceant,
        minblperant = minbaselines, solnorm = False,  gaintype = 'G',
        solint = 'inf', combine = '', calmode='ap',
        gaintable=[calfiles.kcorrfile, calfiles.bpassfile],
        gainfield=[fields.kcorrfield, fields.bpassfield],
        parang = False, append = False)

# Only run fluxscale if bootstrapping
if len(fields.gainfields) > 1:
    fluxscale(vis=visname, caltable=calfiles.gainfile,
            reference=[fields.fluxfield], transfer='',
            fluxtable=calfiles.fluxfile, append=False)
```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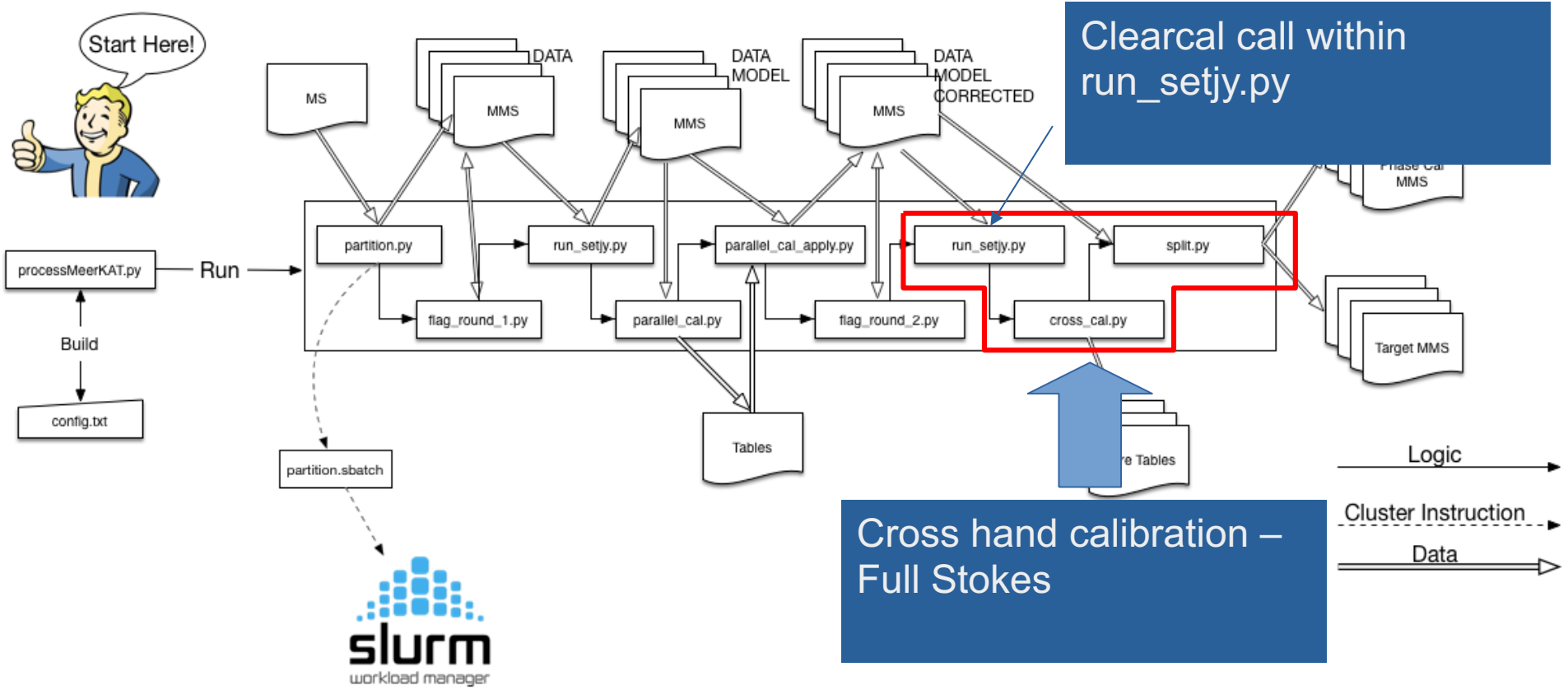
Post calibration flagging –
tighter RFI thresholds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Clearcal call within run_setjy.py
Cross hand calibration – Full Stokes
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Polarization calibration

- Need to estimate :
  - Instrumental leakage
  - Calibrator source polarization
- Do both by observing a single source over several parallactic angles

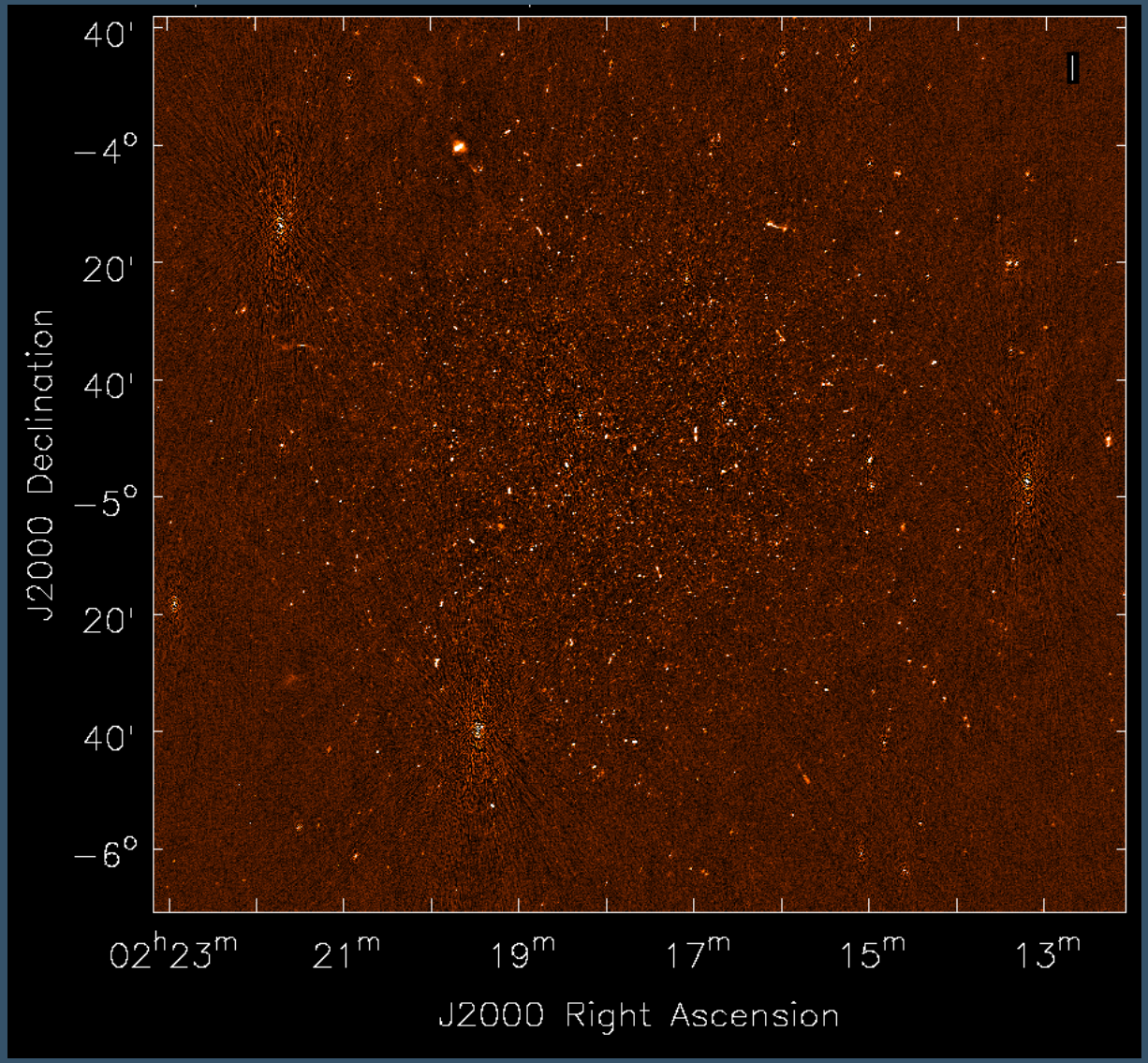
Polarization calibration

- CASA “helper” task GainfromQU estimates Q, U of source from gain variation vs. Parallactic angle
- Use this information to solve for X-Y phase and instrumental leakage

```
gaincal(vis=visname, caltable=gain1file, field=fields.fluxfield,
        refant=referenceant, solint='10min', minblperant=minbaselines,
        solnorm=False, gaintype='G',
        gaintable=[calfiles.kcorrfile, calfiles.bpassfile,
            calfiles.xdelfile],
        gainfield = [fields.kcorrfield, fields.bpassfield,
            fields.xdelfield], append=False, parang=True)

gaincal(vis=visname, caltable=gain1file, field=fields.secondaryfield,
        smodel=[1,0,0,0], refant=referenceant, solint='10min',
        minblperant=minbaselines, solnorm=False, gaintype='G',
        gaintable=[calfiles.kcorrfile, calfiles.bpassfile,
            calfiles.xdelfile],
        gainfield = [fields.kcorrfield, fields.bpassfield,
            fields.xdelfield],
        append=True, parang=True)

# implied polarization from instrumental response
logger.info("\n Solve for Q, U from initial gain solution")
GainQU = qufromgain(gain1file)
logger.info(GainQU[int(fields.dpolfield)])

logger.info("\n Starting x-y phase calibration\n → %s" % xy0ambpfile)
gaincal(vis=visname, caltable = xy0ambpfile, field = fields.dpolfield,
        refant = referenceant, solint = 'inf', combine = 'scan',
        gaintype = 'XYf+QU', minblperant = minbaselines,
        smodel = [1.,0.,1.,0.], preavg = 200.0,
        gaintable = [calfiles.kcorrfile,calfiles.bpassfile,
            gain1file, calfiles.xdelfile],
```

Polarization calibration

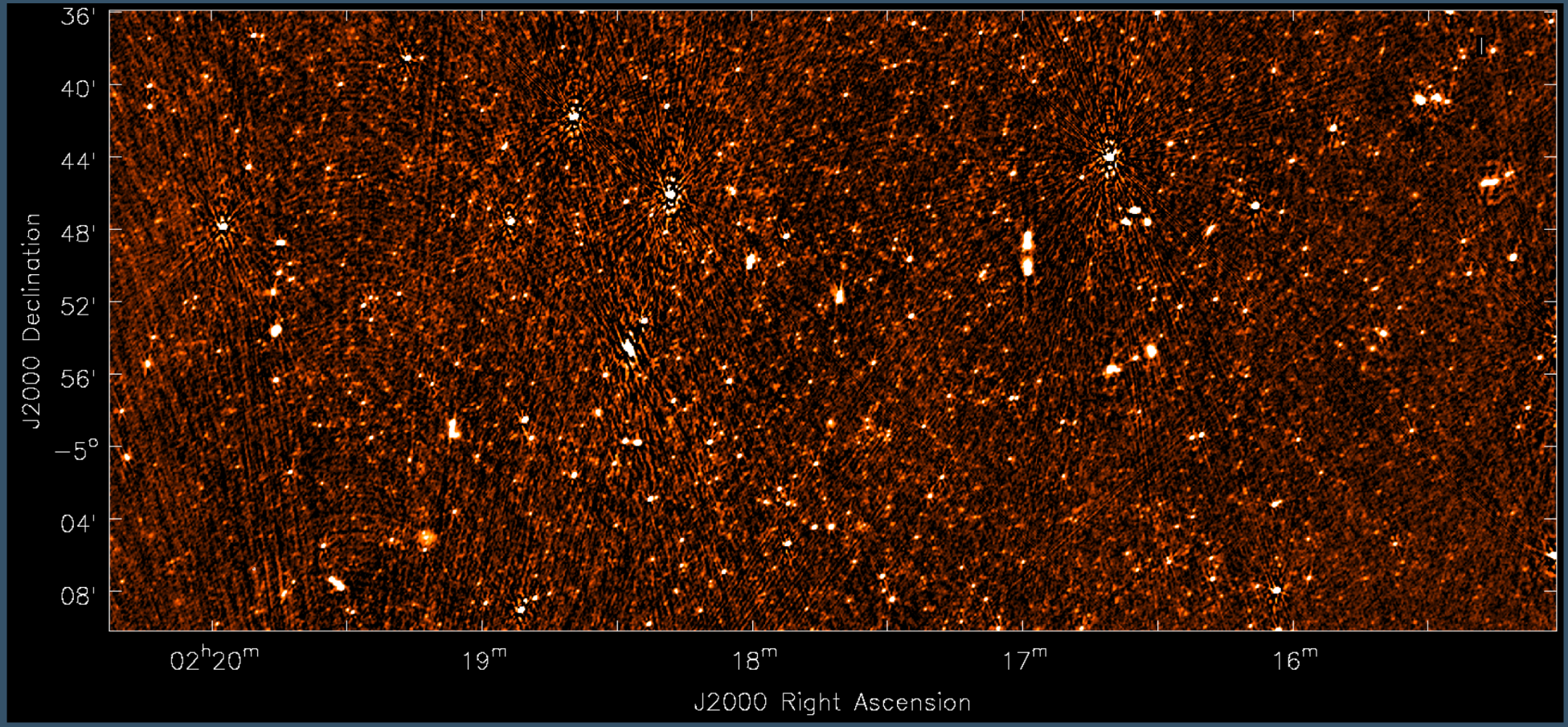
- Limitations: Leakage and QU estimation assume a constant value across an SPW.
  - Reasonable for VLA/ALMA, with several small (~ 64 MHz) SPWs
  - Problematic for MeerKAT with one ~ 800 MHz SPW
- On axis calibration still good, in reasonable agreement with VLA polarization measurements



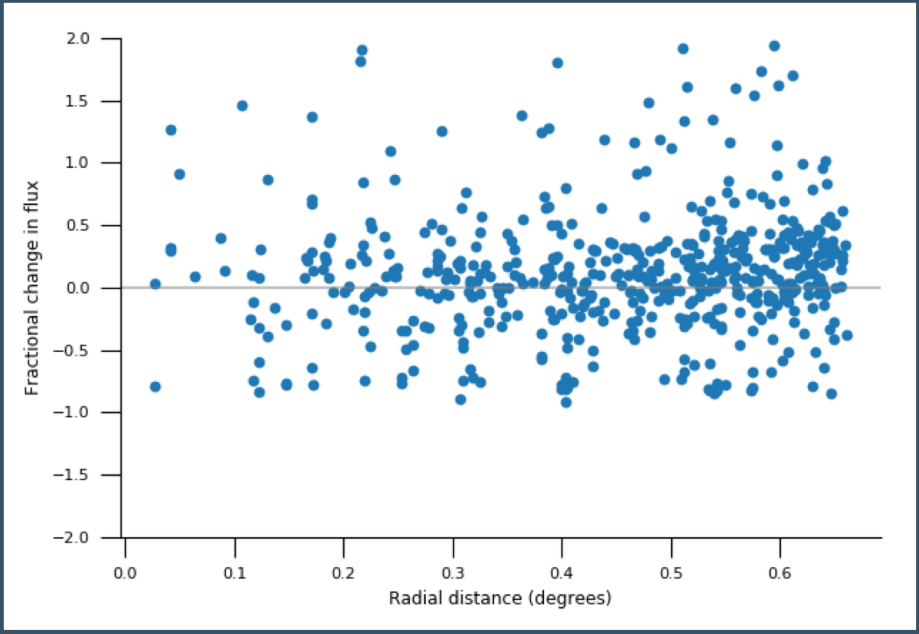
MIGHTEE XMM LSS 12

RMS : ~ 4 uJy/beam

Self-cal improvements

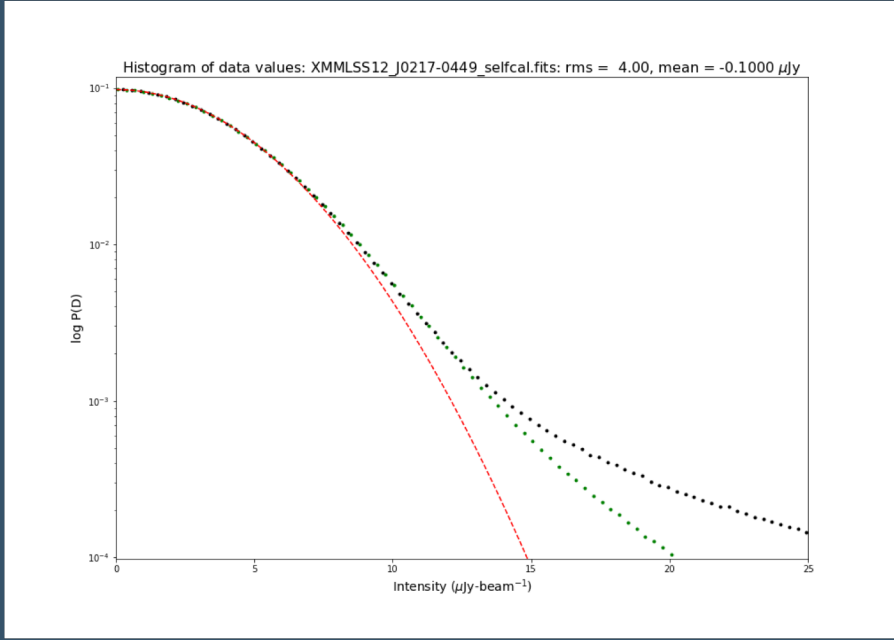


Fluxes



VLA vs MeerKAT XMM LSS

Catalogs courtesy Ian Heywood

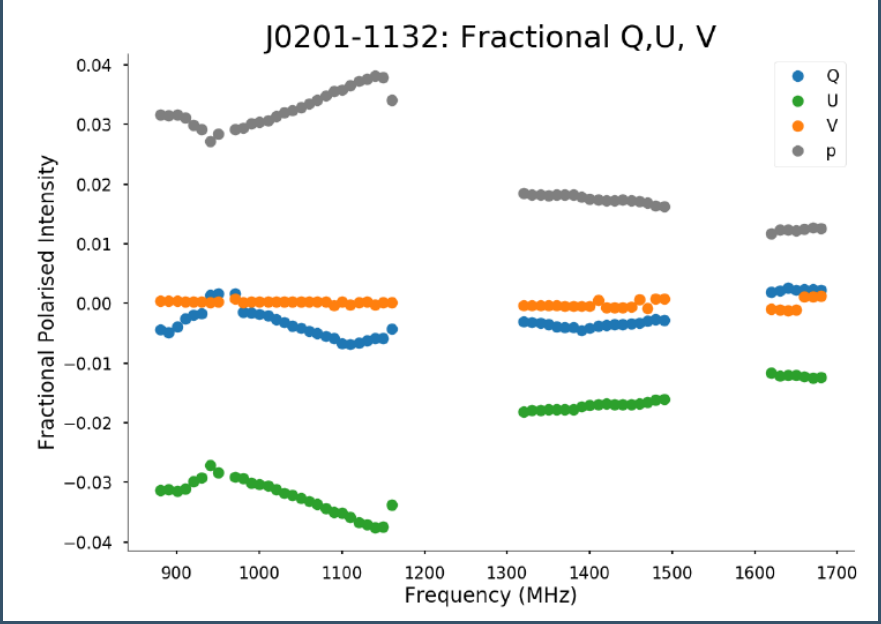


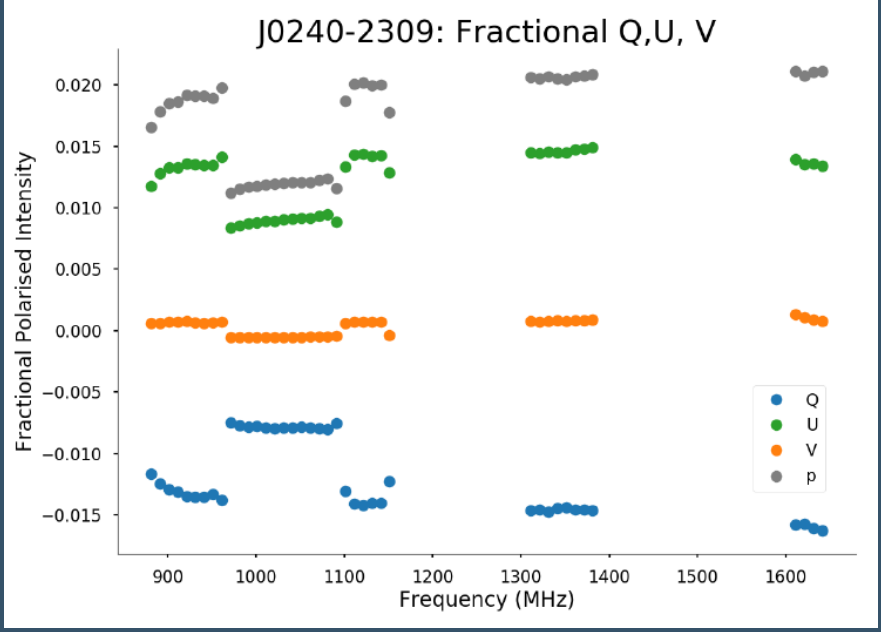
Pixel histogram of the MeerKAT XMM LSS image

Plot courtesy Russ Taylor

Polarization cubes

- Stokes V a good indicator of calibration quality

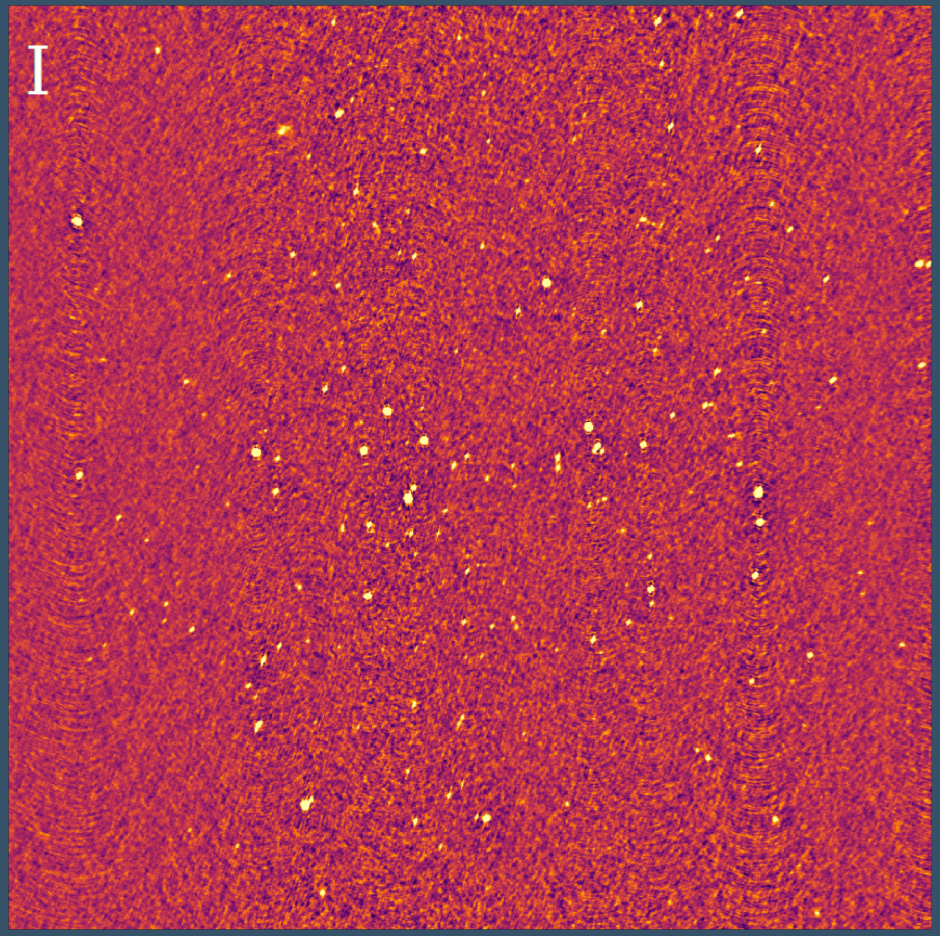




Fractional polarization

Calibrator	Field	NVSS (1.4 Ghz) %	MeerKAT band average (1.2 Ghz) %
J0240-2309	CDFS	0.80	1.72
3C237	COSMOS	< 0.13	0.1
J0201-1132	XMM LSS	3.41	2.31

Polarization cubes



Stokes images of a single channel of the XMM LSS pointing at 1120 MHz

Next steps

- Get off-axis, wideband polarizations working
  - Full Stokes AW projection in collaboration with NRAO, talk this afternoon
- Get more reliable wideband polarization
  - CASA is not RM “aware” over a wideband, single SPW. Workarounds are being tested.

Summary

- The IDIA pipeline produces Stokes I images with ~ 8-10 uJy/beam rms with no self-cal, and (currently) 4 uJy/beam after self-cal
- Fluxes typically accurate to ~ 5%
- On axis polarization is good, but will improve once the wideband is accounted for correctly