

Can EoR processing techniques be used for other science cases?

LOFAR annual meeting 2026-06-08
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EoR processing

Crucial concept for 21-cm EoR signal extraction:

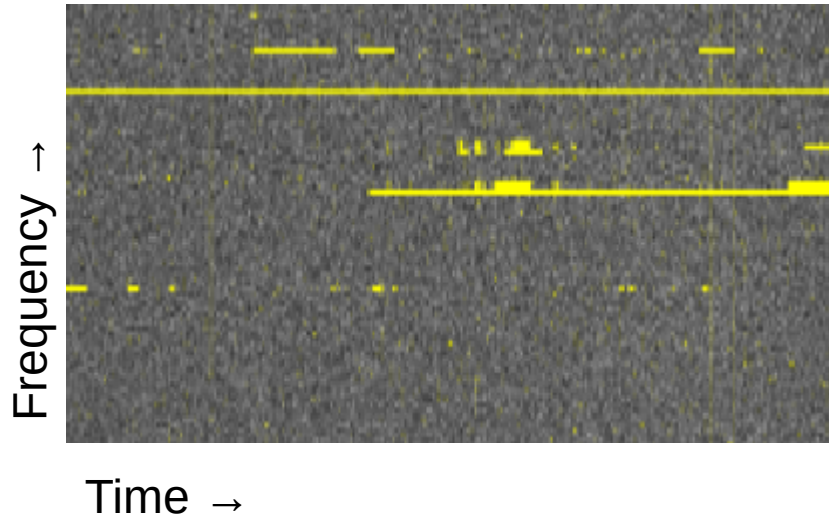
Spectral smoothness of foreground and instrument

What happens in preprocessing

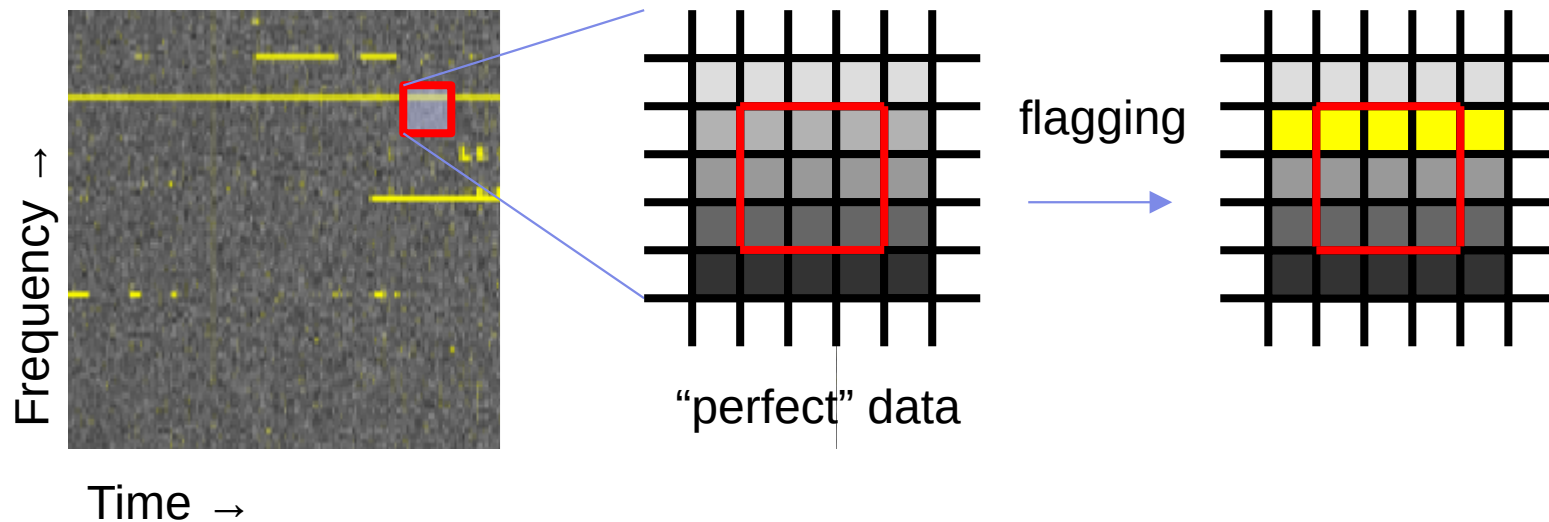
- **Typical input:** 64 channels/subband, 1 second visibilities
 - In special “LOFAR storage manager” format
 - Future: stream directly from correlator (talk by Mick Veldhuis tomorrow)
- **Determine visibility weights**
- **Flag** (at high resolution), RFI and sub-band edges
- **Average:** typically to 16 ch/sb 1 s
- **A-team subtraction** using demixing (for LBA)
- **Compress** with Dysco
- **Write** in ‘normal’ MS format
 - Next pipeline: LINC for imaging or EoR DI cal for EoR

In-painting, weights and compression

RFI looks like this:

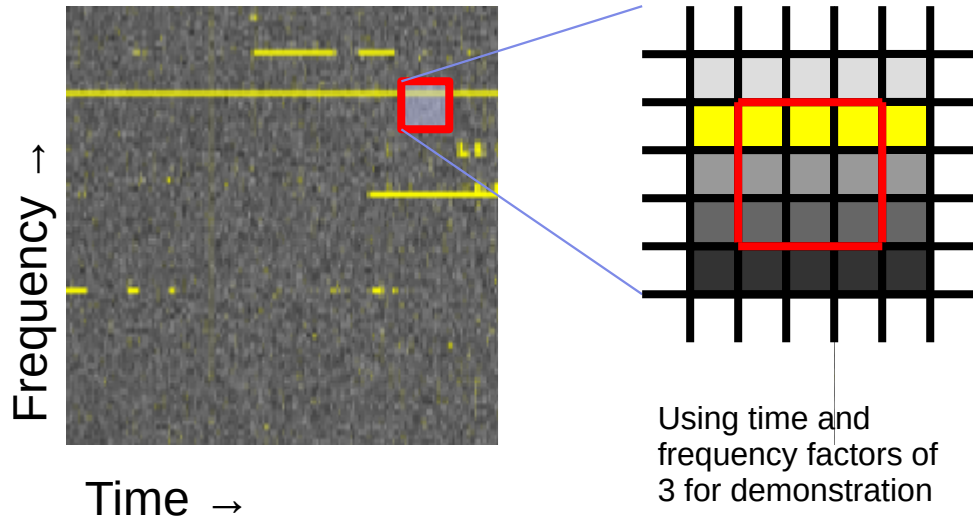


In-painting, weights and compression



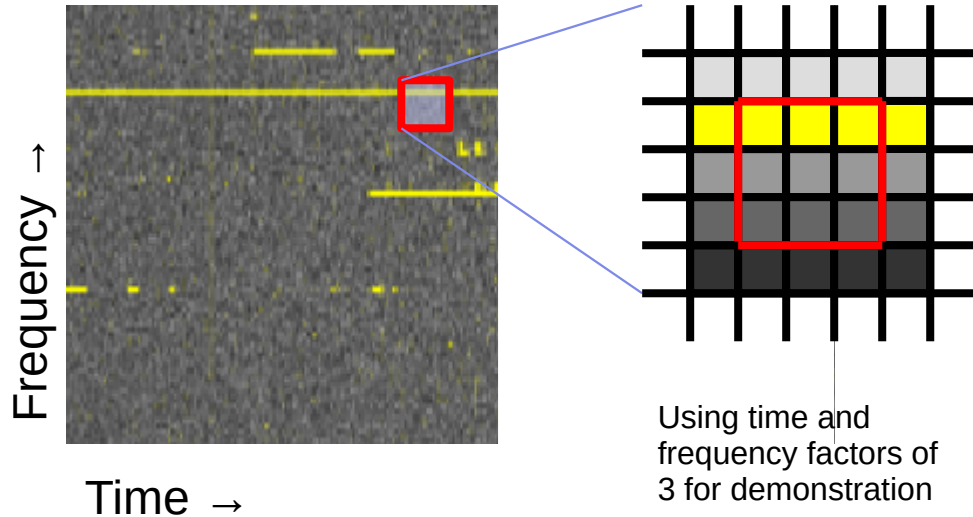
In-painting, weights and compression

What happens with the data during averaging? (*)

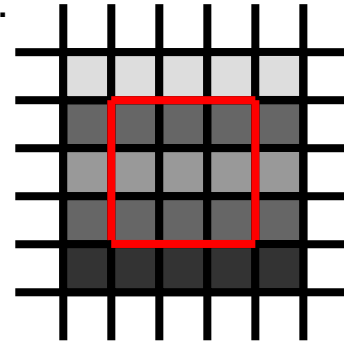


(*) Gridding is similarly affected

In-painting, weights and compression



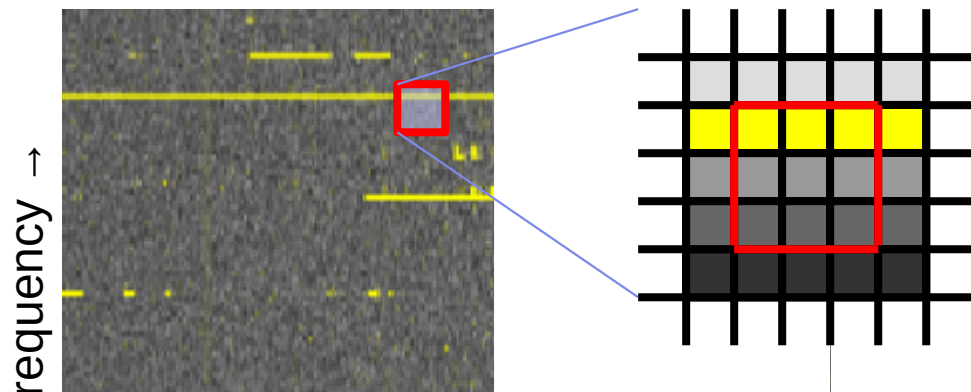
Flags are ignored: it is as if they are in-painted by the average of the box:



Result: systematic bias & frequency fluctuations

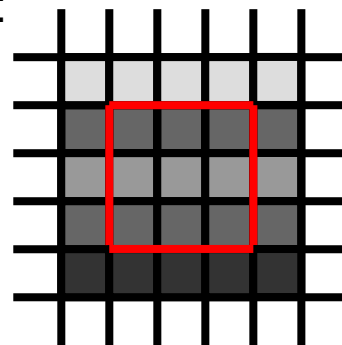
(*) Gridding is similarly affected

In-painting, weights and compression



A similar issue occurs in flagging of the subband edges

Flags are ignored: it is as if they are in-painted by the average of the box:



Result: systematic bias & frequency fluctuations

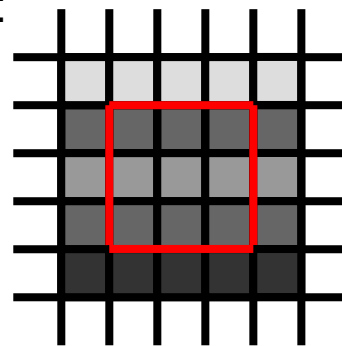
(*) Gridding is similarly affected

In-painting, weights and compression

This can not be corrected by changing UVW coordinates:

- UVWs are stored in meters and shared by the channels of one baseline
- For forward modeling, it would require the high-resolution *weights* (not just flags)
- Even when taking this all into account, we saw that it still breaks smoothness (because channels are processed differently)

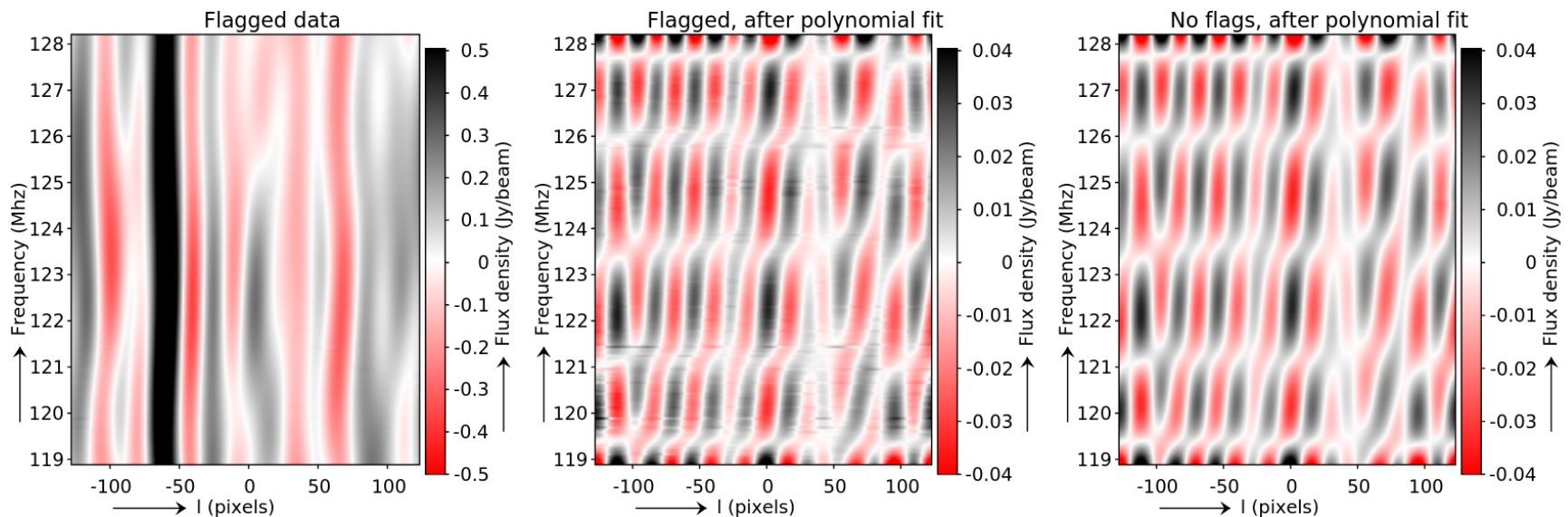
Flags are ignored: it is as if they are in-painted by the average of the box:



Result: systematic bias & frequency fluctuations

Breaking smoothness by flagging

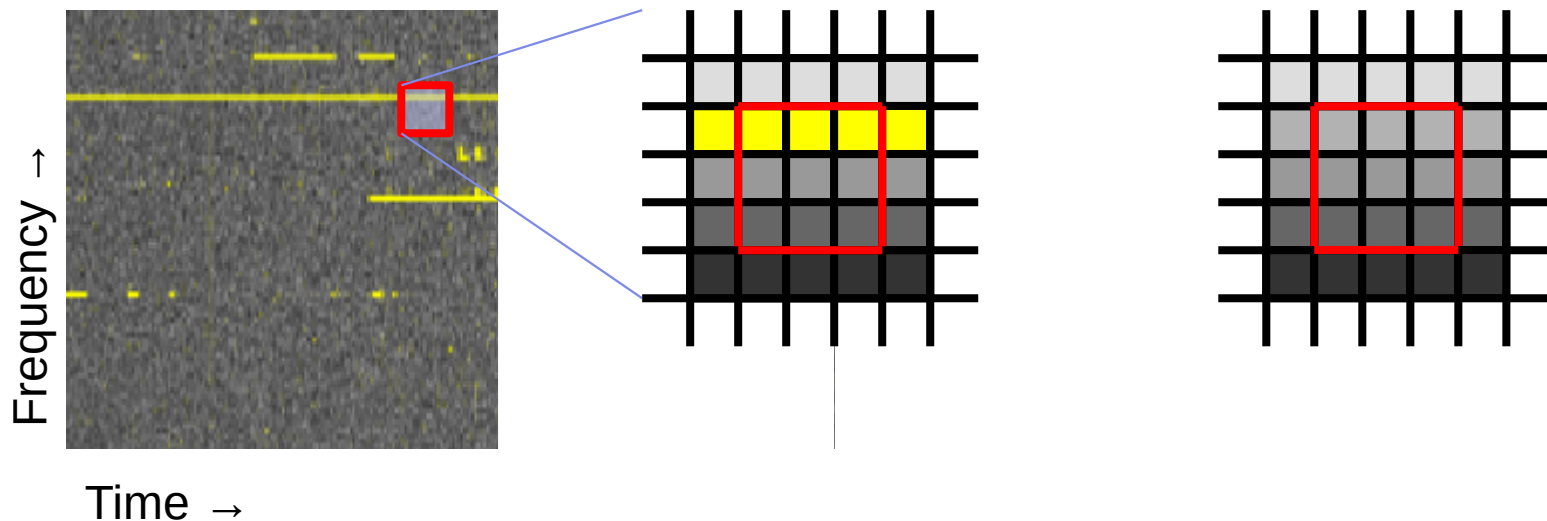
- Result:



Offringa, Mertens & Koopmans (2019)

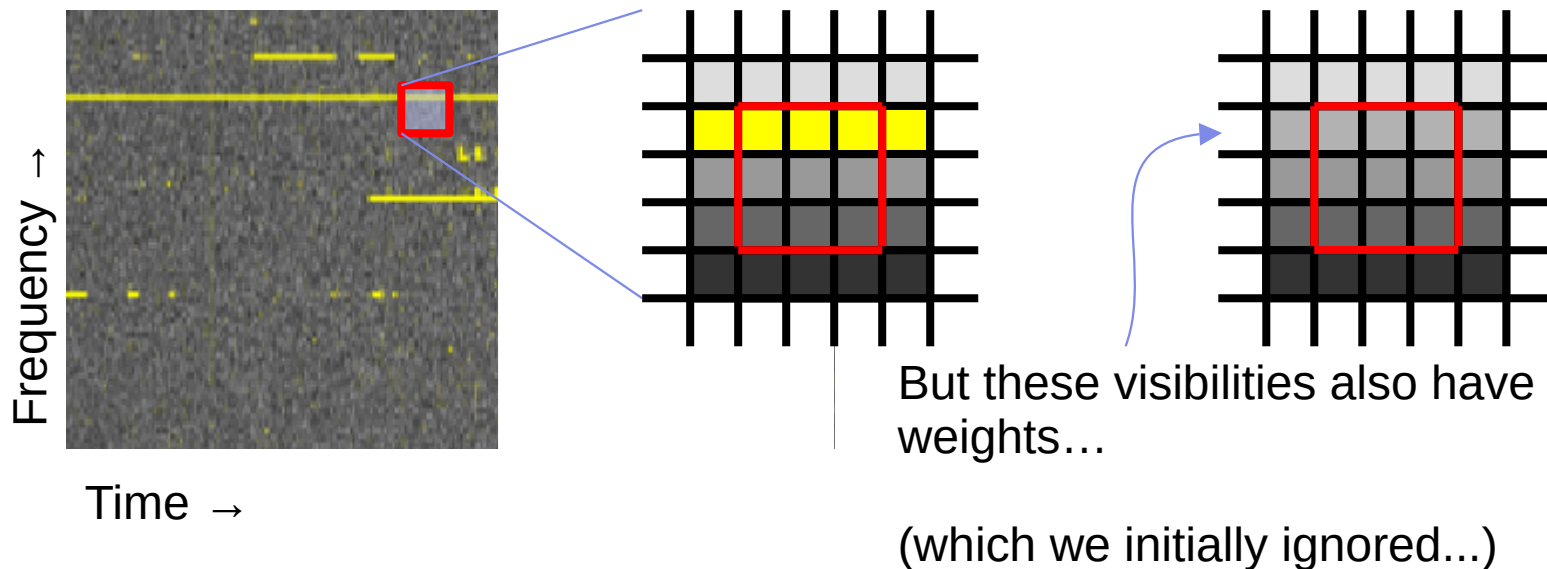
In-painting, weights and compression

Solution: using explicit in-painting
E.g. Gaussian interpolation:

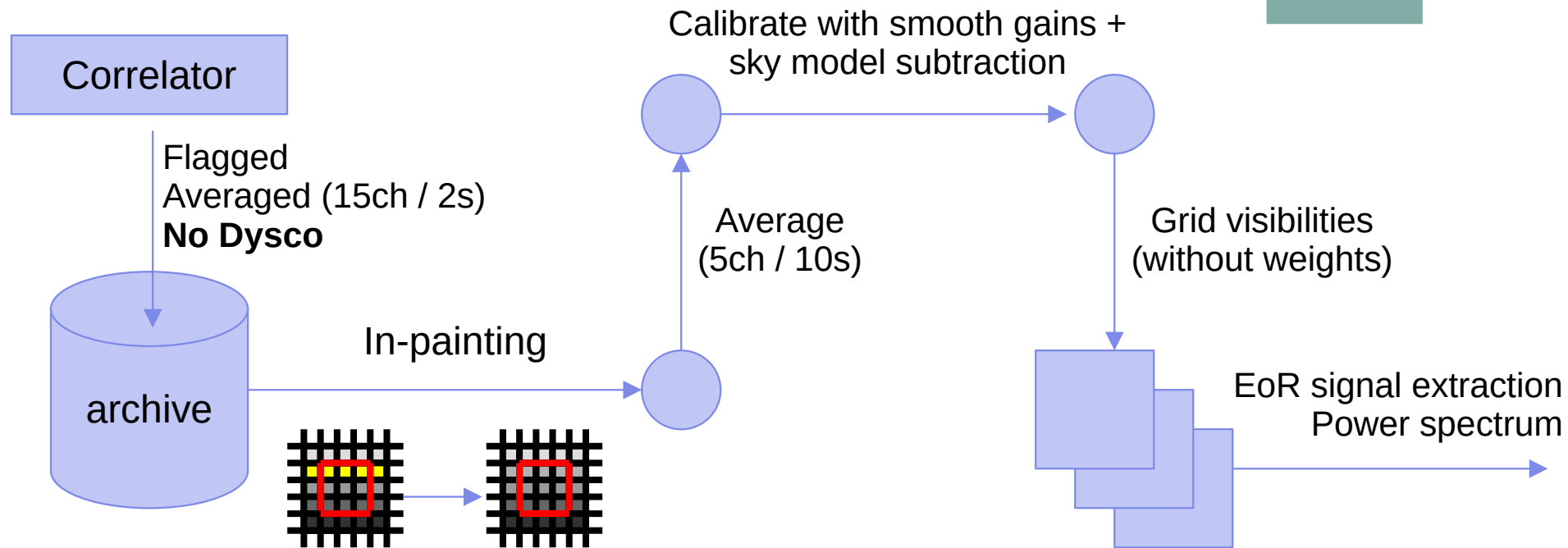


In-painting, weights and compression

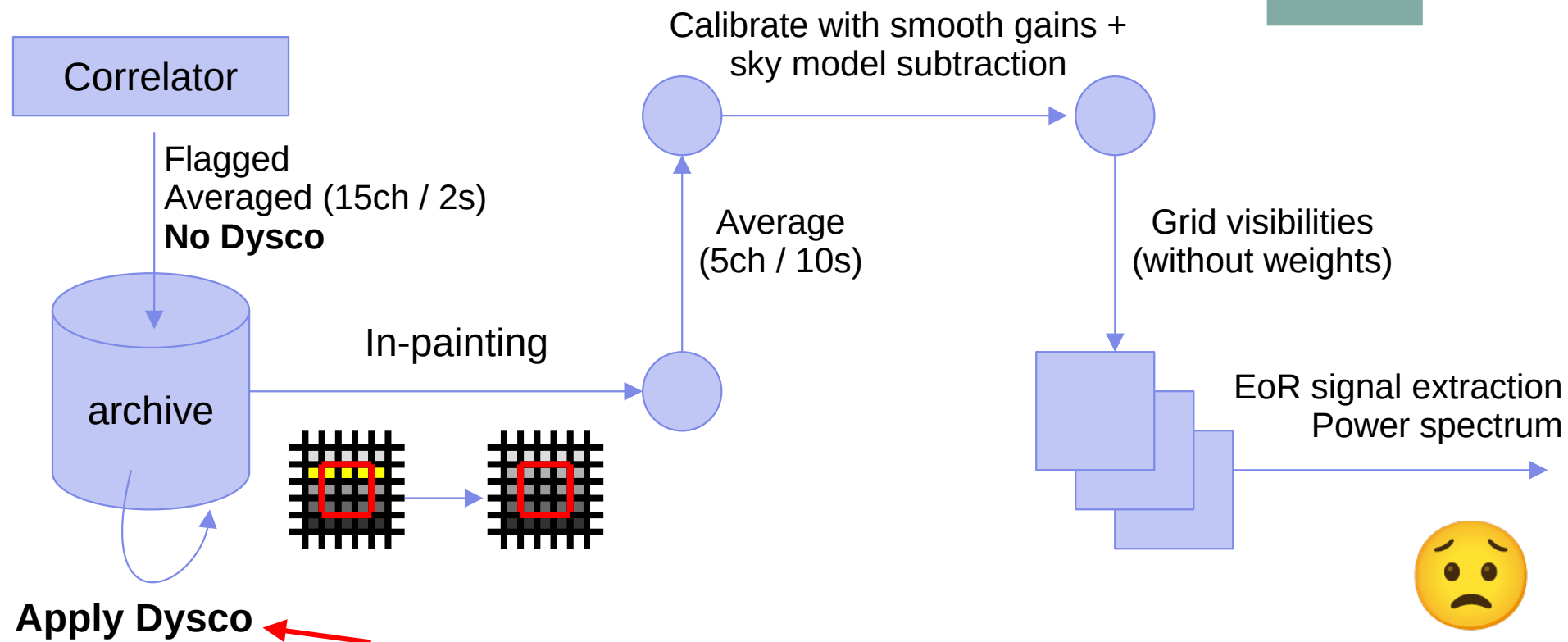
Solution: using explicit in-painting
E.g. Gaussian interpolation:



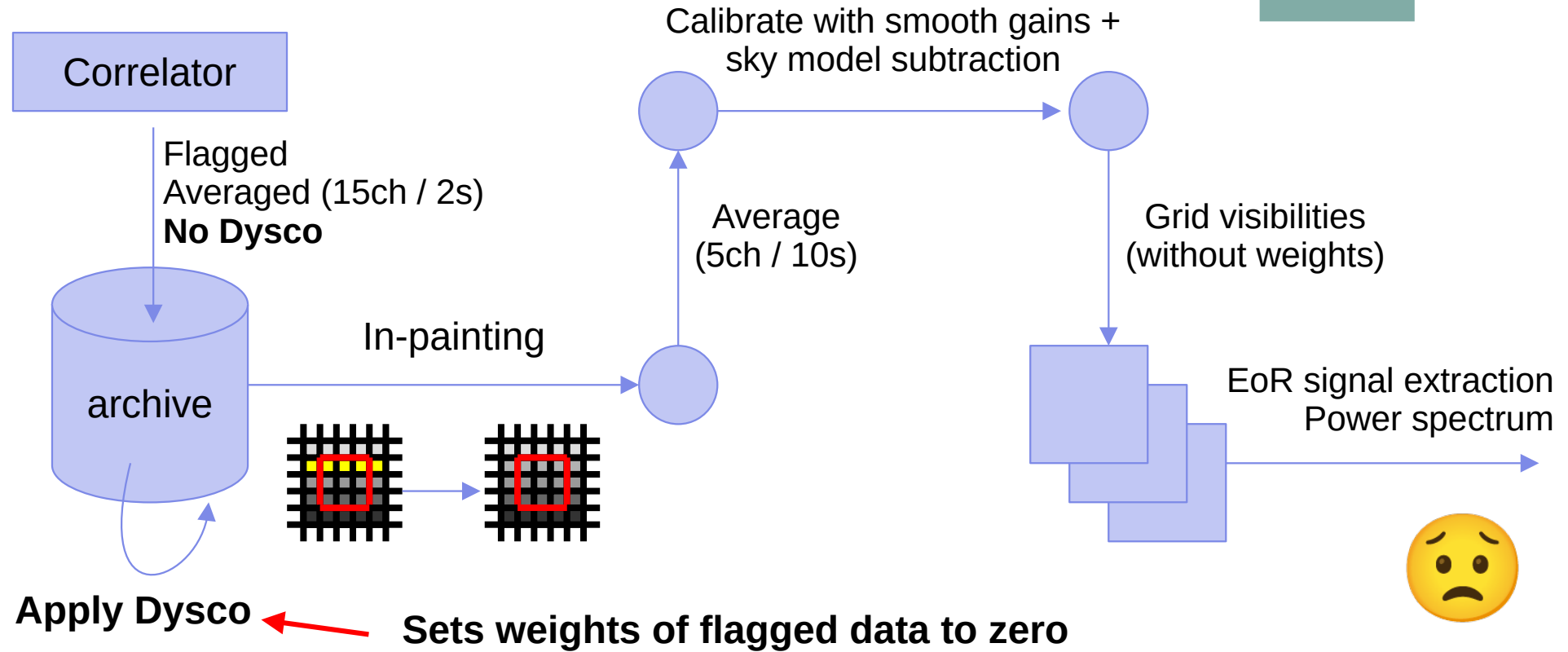
EoR processing steps



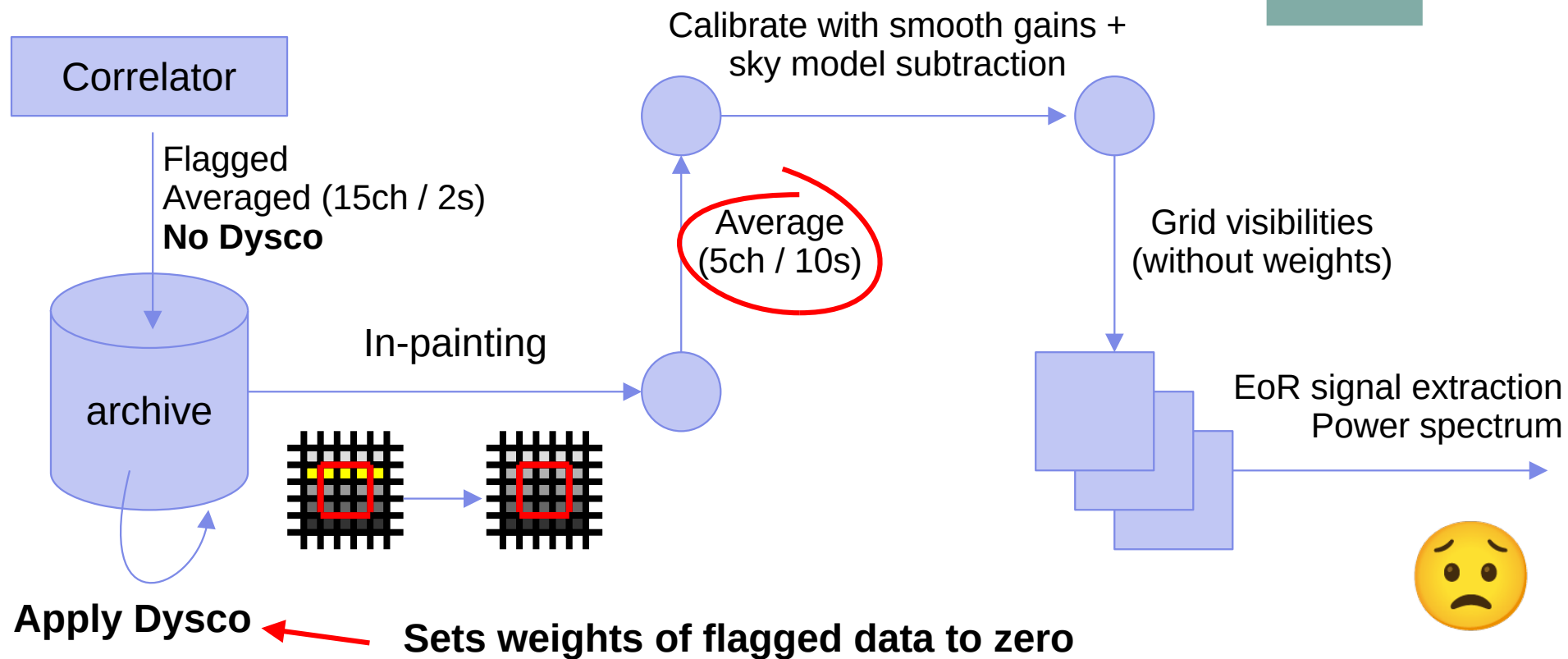
EoR processing steps



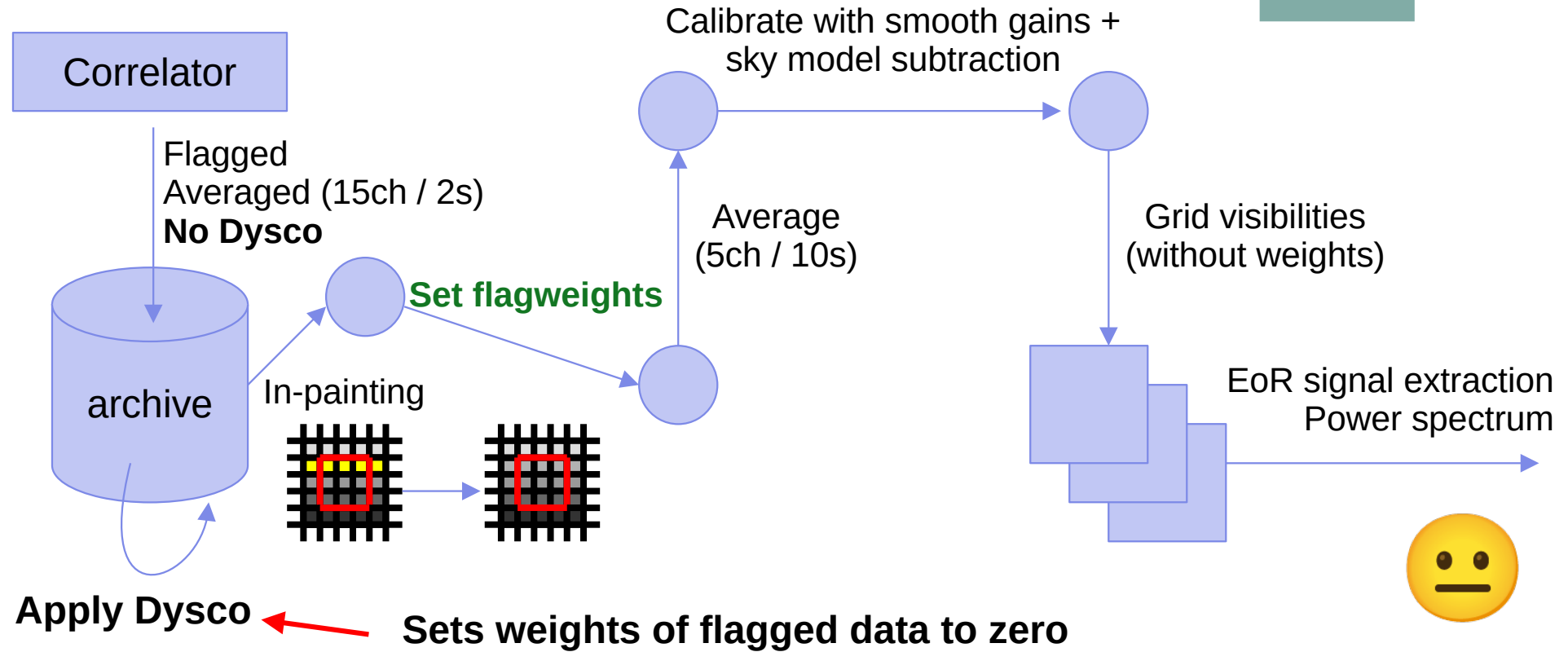
EoR processing steps



EoR processing steps



EoR processing steps



Dysco after setting flag weights

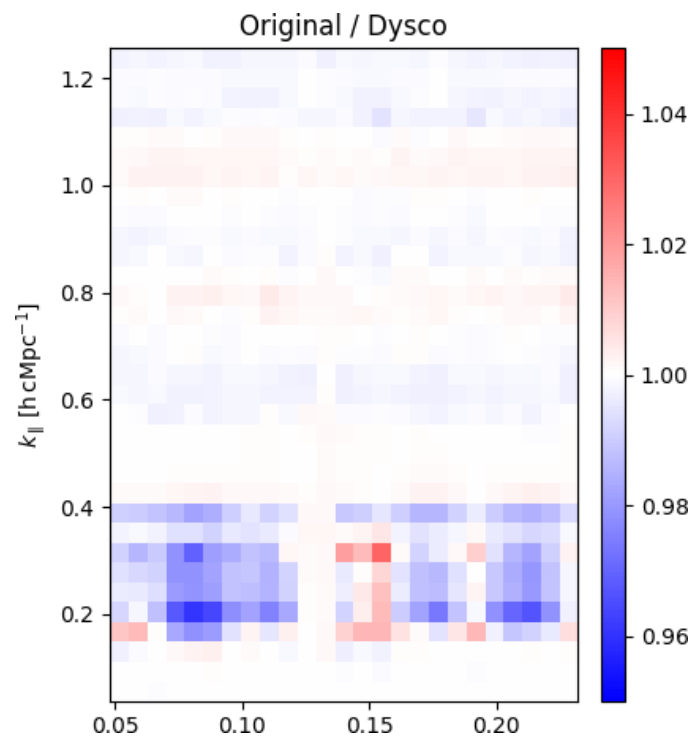
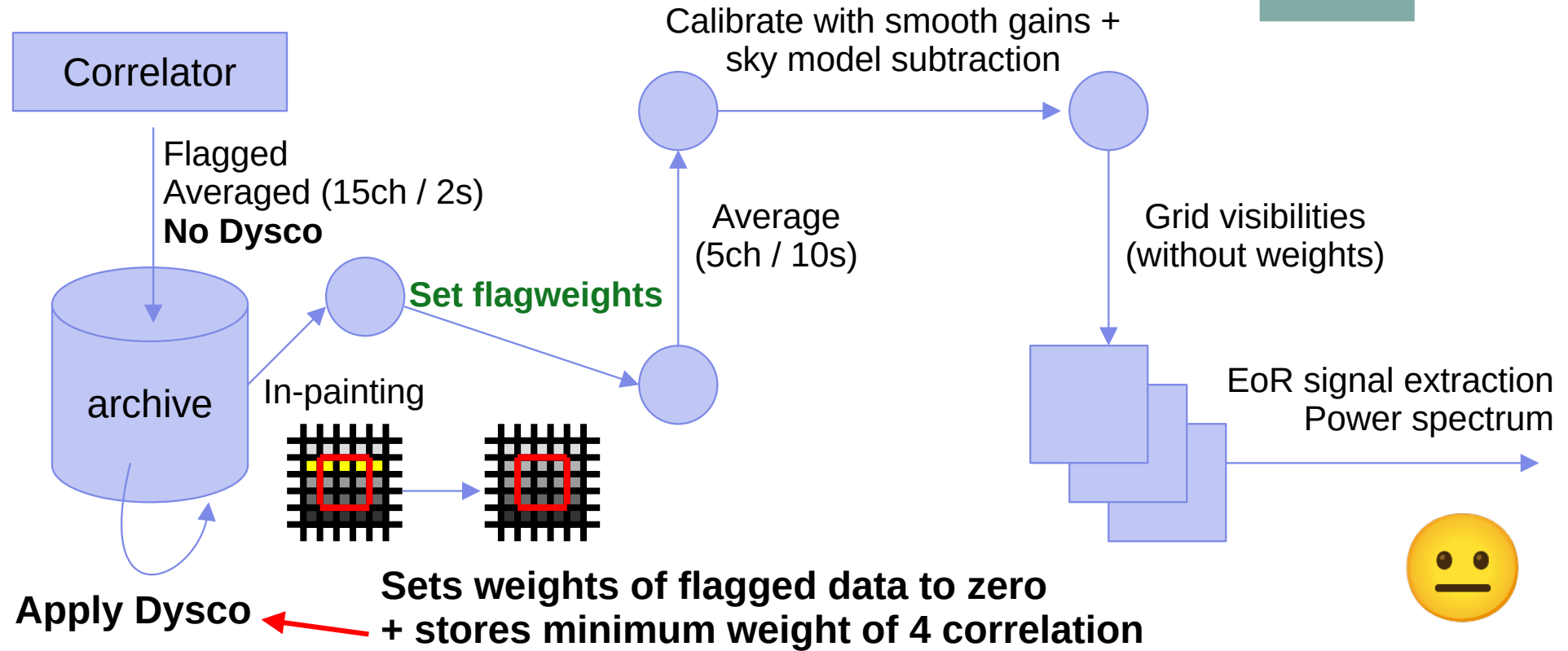


Image by K. Chege

EoR processing steps



How to store one weight per 4 correlations?

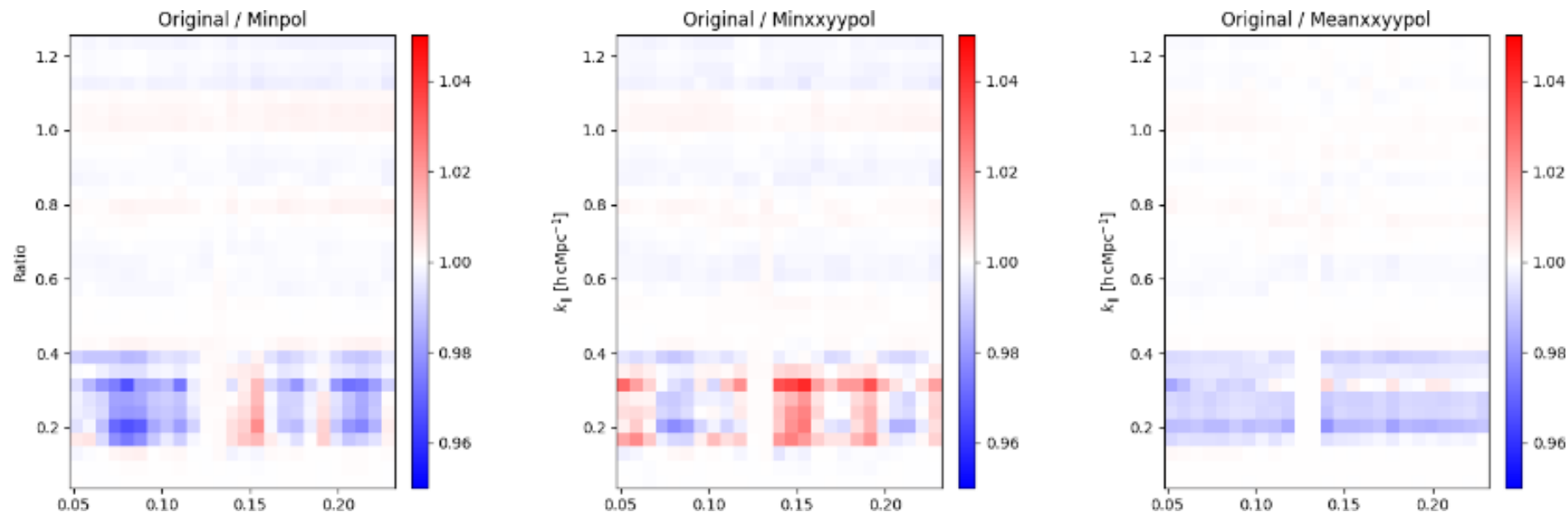


Image by K. Chege

Dysco lessons

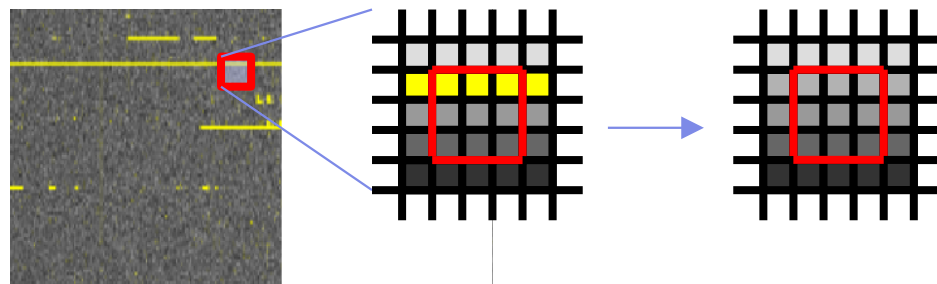
What we learned specifically for our analysis:

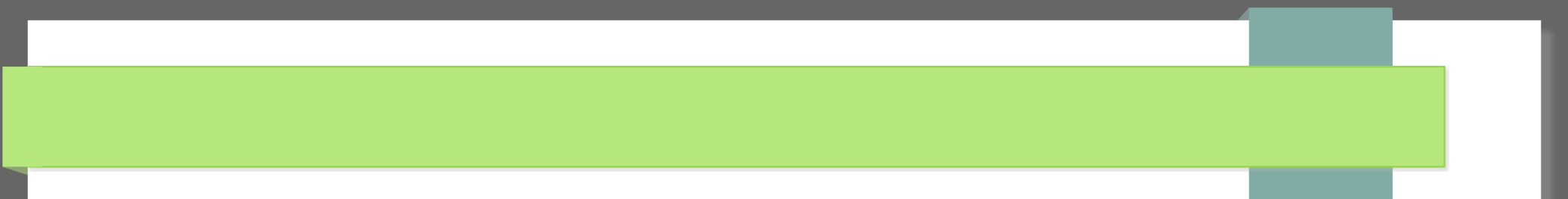
- During in-painting, weights have to be interpolated too
- Weight compression has an effect on spectral smoothness
 - Better to take the average of w_{xx} and w_{yy} instead of minimum of 4
 - Probably not a generic conclusion → Might hold only for spectral smoothness requirement + Stokes I imaging
- Dysco visibility compression does not introduce artefacts (Chege et al. 2024)

Use of interpolation

Can we use interpolation in all preprocessing?

- Existing Dp3 step: *interpolate*
- Provides higher quality results in averaging
 - Important for science cases that require smoothness (EoR, line)
- But preprocessing “can not be undone”
- Needs testing

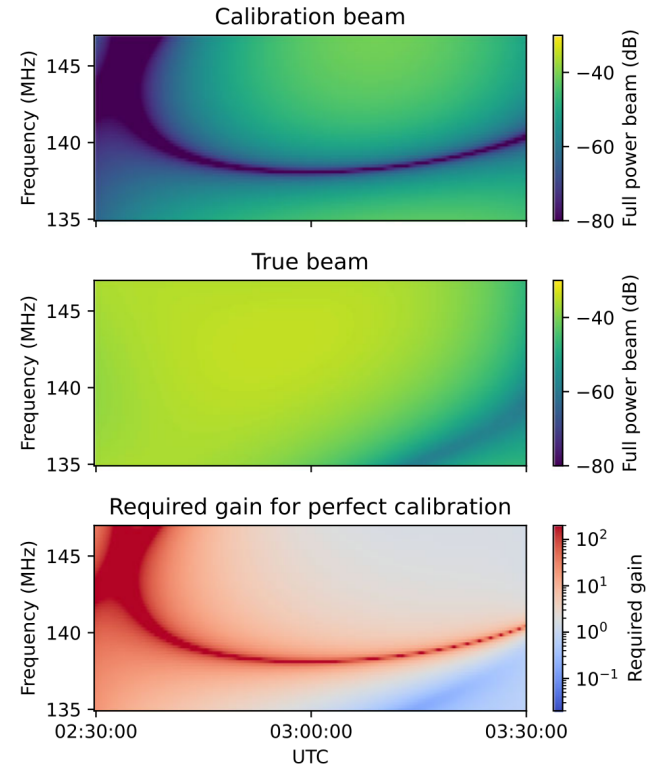




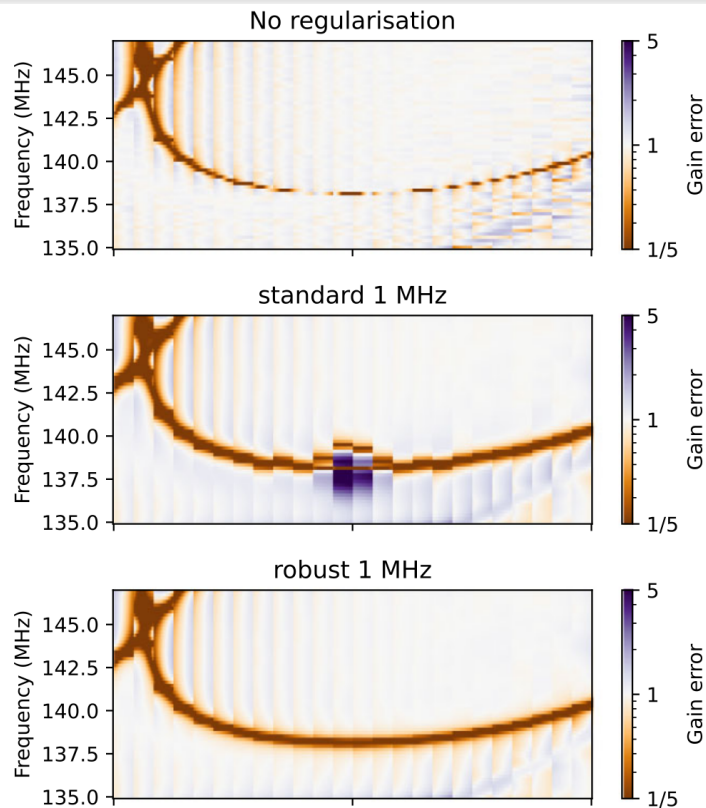
Robust calibration

Robust calibration

- The “calibration beam” is not fully accurate
- Imperfect tiles/antennas move the beam’s null
 - Affects a-team sources
- Causes bad calibration when smoothness constraint is used



Robust calibration



- Robust calibration solves this partially (see Brackenhoff et al. 2025)
- Performs ‘weighted smoothing’
- Dp3 ddecad option:

`ddecad.model_weighted_constraints = true`

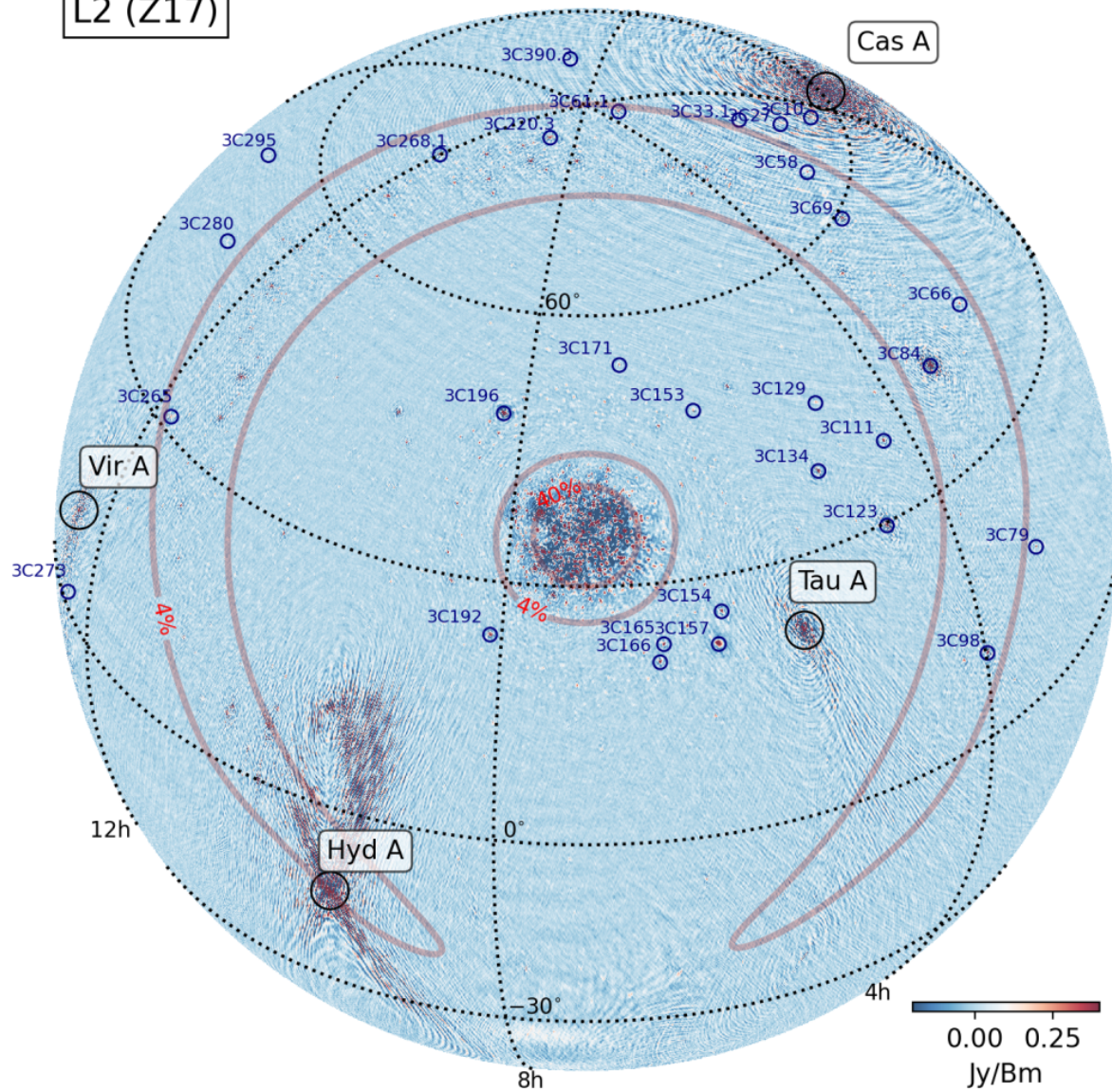
Cygnus A gains

Demixing & a-team subtraction

- A-team subtraction is crucial for EoR signal recovery
...and also for LBA imaging
 - Common LOFAR LBA approach: demixing; a specific solver algorithm
 - In EoR processing, we do not demix
- We subtract sources *after averaging*, and use smoothness + robust
 - Demixing has fewer features (⚠ no smoothness constraint)
 - Demix code is getting old and unmaintained
- Question for you:
 - *Can we use ddecals instead of demixing for LBA processing?*

See also: Gan et al. (2022), Munshi et al. (2025), Ceccotti et al. (2025)

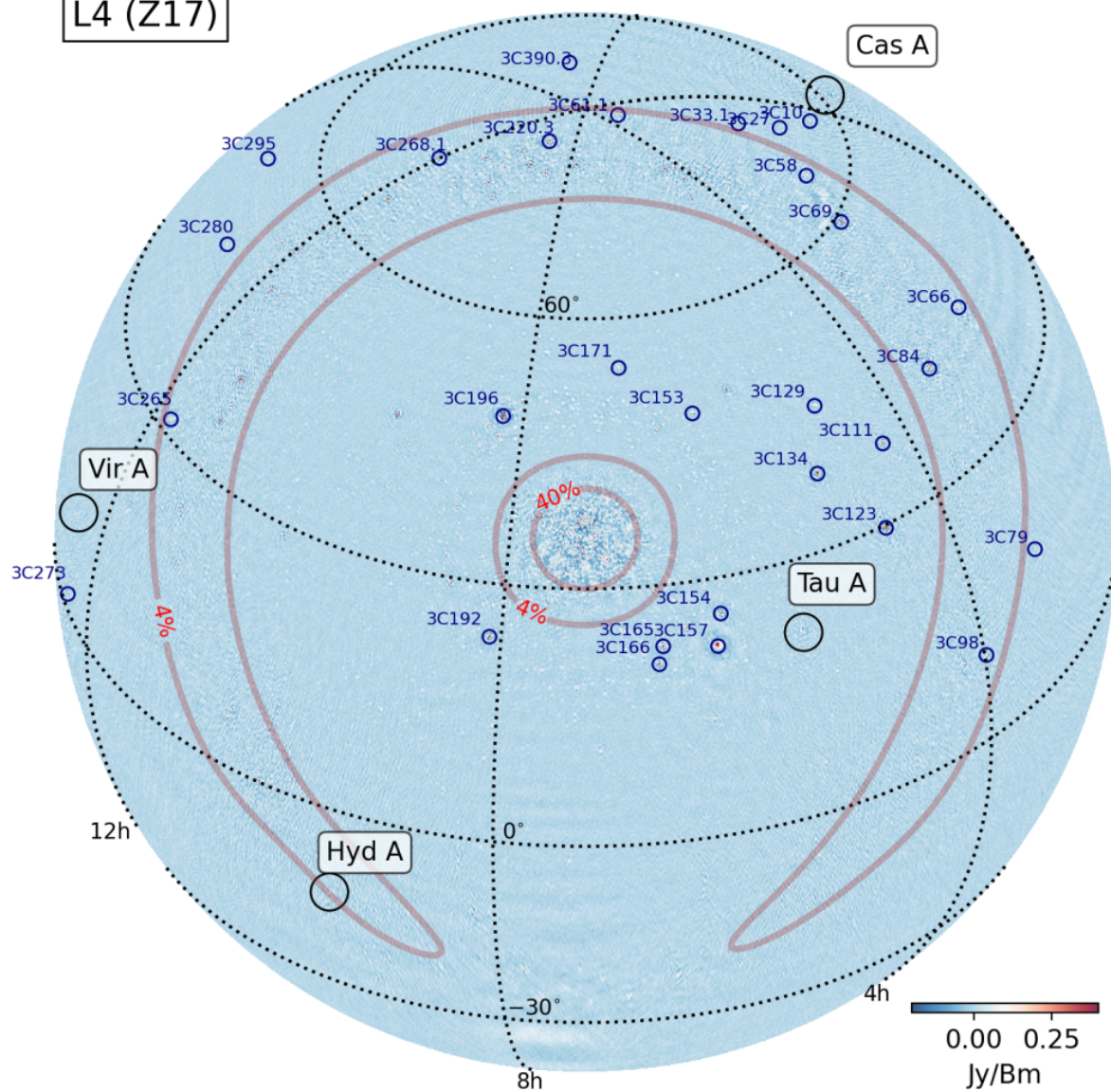
L2 (Z17)



- NenuFAR dirty image (61-85 MHz)
- Very bright a-team sources in sidelobes

(Munshi et al. 2025)

L4 (Z17)



- NenuFAR dirty image (61-85 MHz)
- Very bright a-team sources in sidelobes

(Munshi et al. 2025)

Summary and questions to you

- Weights should not be ignored
 - Dysco weight compression may be optimized slightly (sub % effect on imaging)
- Can interpolation be used in preprocessing?
 - Better averaging quality
 - Is our subband edge flagging strategy optimal?
 - Have to consider weighting
- Should we make robust calibration the default?
 - Better off-axis source subtraction
- Can demixing be replaced in LBA preprocessing?
 - Use ddecad instead
 - May use smoothness constraint for higher S/N (with robustness)
 - Good results in EoR processing, even possible after averaging

