Blind 21-cm absorption survey in GAMA-23

Methods, challenges and future prospects

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THE AUSTRALIAN SKA PATHFINDER

ASKAP EARLY SCIENCE PROGRAM

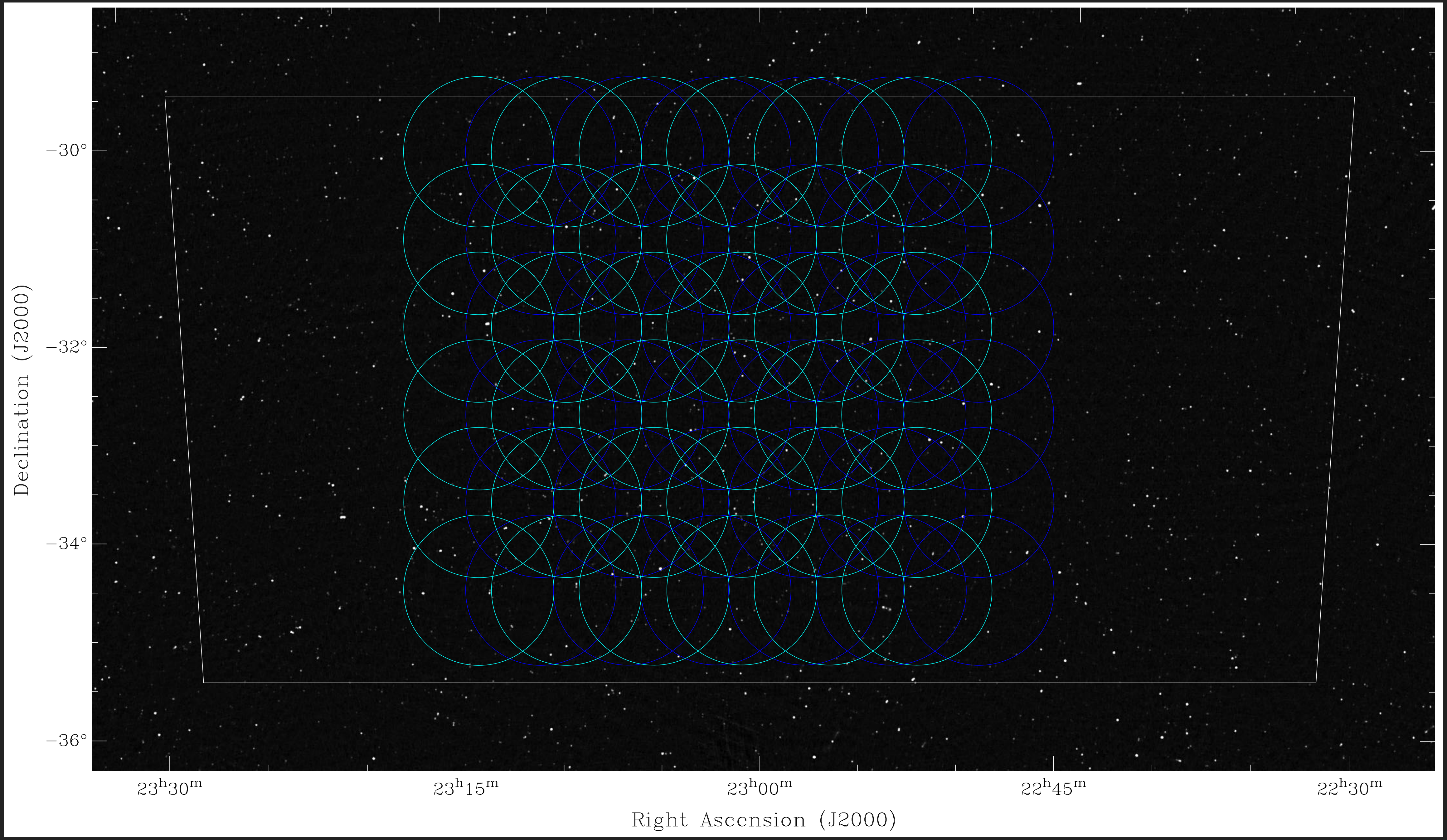
- Observations with 12 - 16 ASKAP dishes during 2016 - 2018
- Several fields selected by WALLABY HI emission survey to study galaxy groups at z ~ 0
- Several wide fields selected by EMU Continuum survey at all frequency bands (700 – 1800 MHz)
- FLASH survey team has two focuses during early science:
  - 1) Targeted observations of individual radio-loud AGN
  - 2) Piggybacking on above fields for absorption science

GAMA 23 HR FIELD

- 23 hr field of the Galaxy and Mass Assembly survey
- Most southerly of 5 GAMA fields at -32 degrees
- 50 square degrees (~0.2% FLASH)
- Wealth of spectroscopic and panchromatic photometric data spanning far-UV through to far-IR (e.g. Driver et al. 2016)
- Redshifts complete to $i_{\mathrm{Kron}} < 19.2$ mag

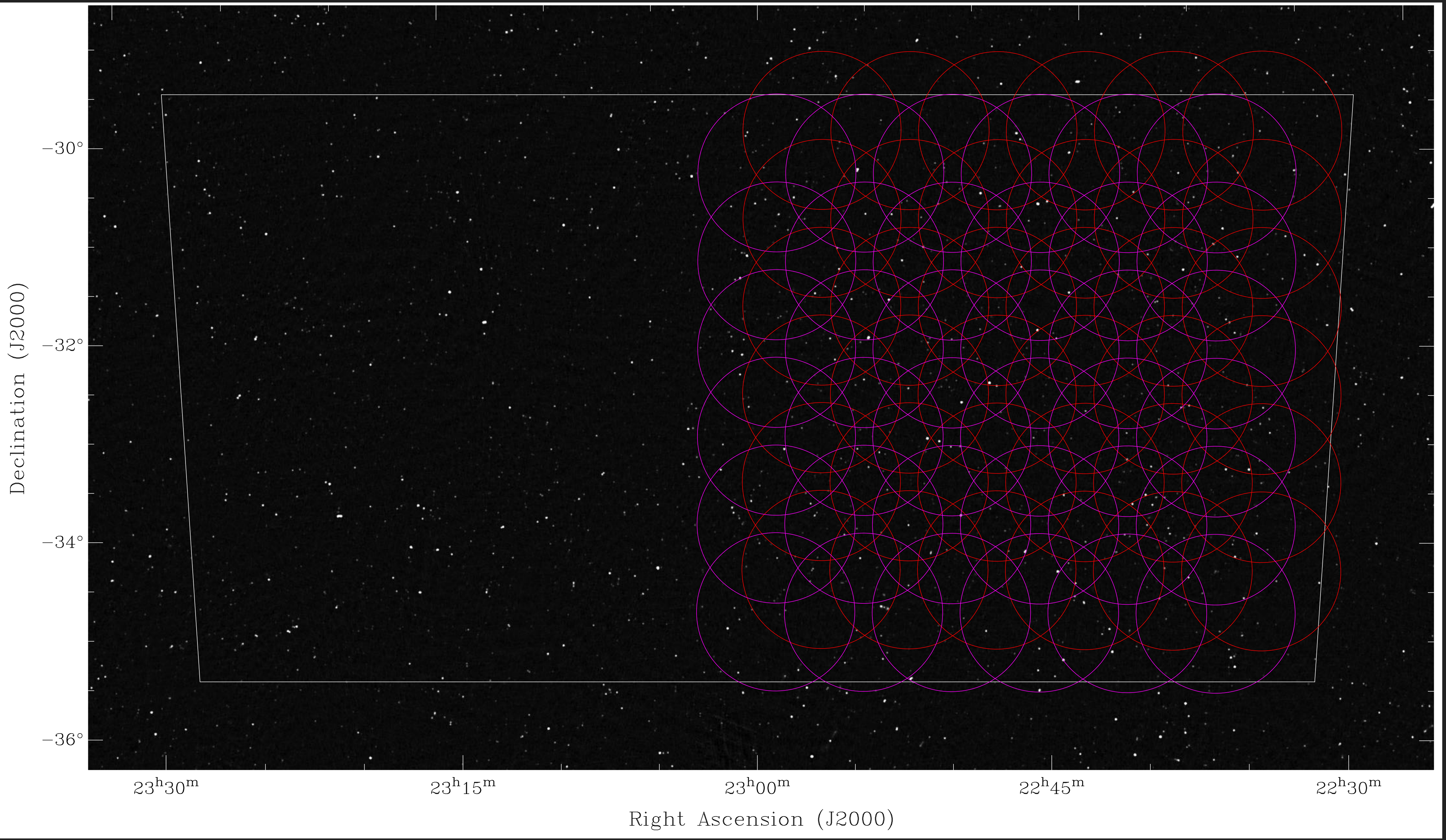
ASKAP OBSERVATIONS OF G23 FIELD

- 17/18-DEC-2016, 864.5 - 1056.5 MHz, 12 ant, 8 hrs



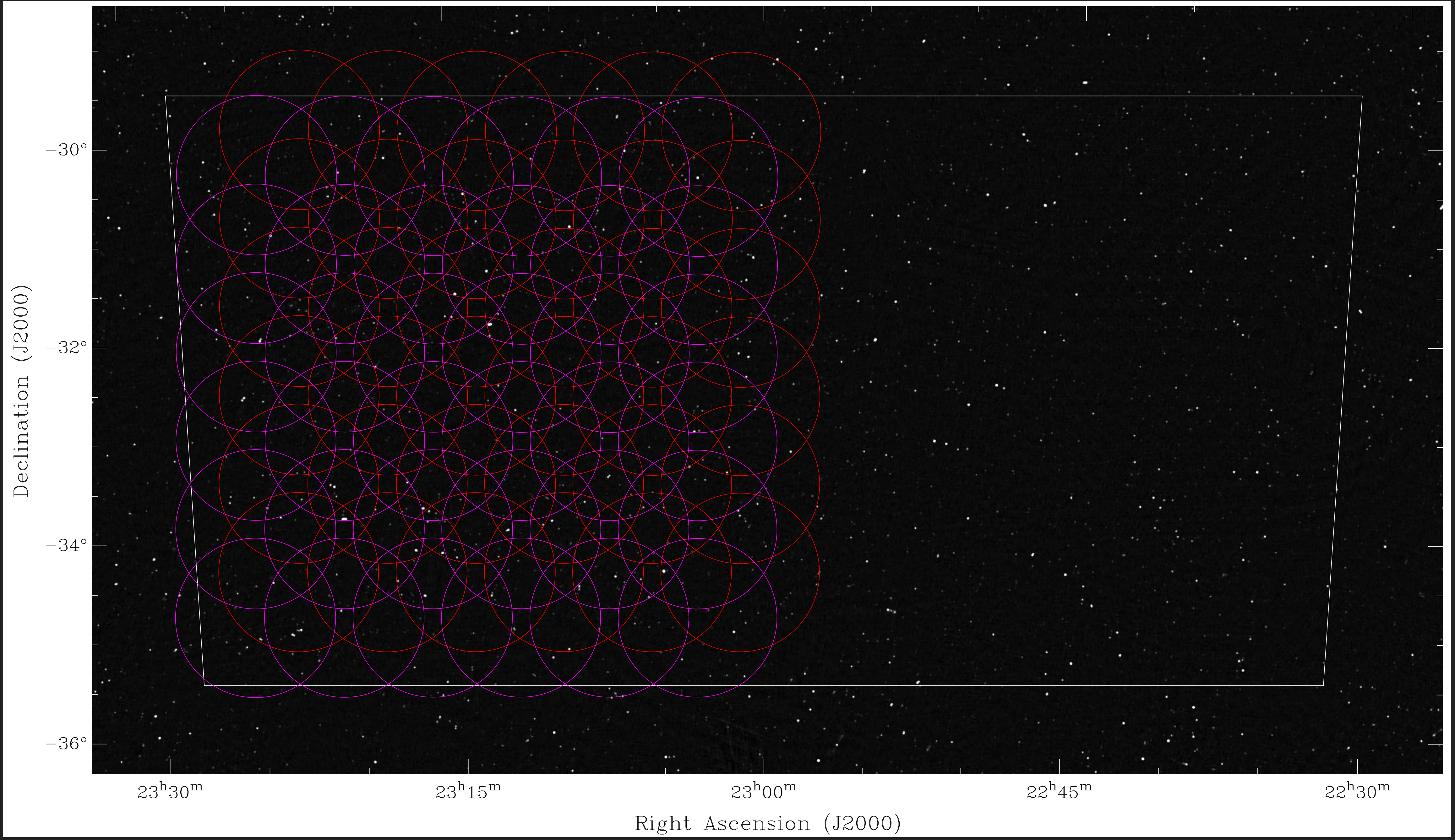
ASKAP OBSERVATIONS OF G23 FIELD

- 13-JAN-2018, 792.5 - 1032.5 MHz, 15 ant, 11 hrs



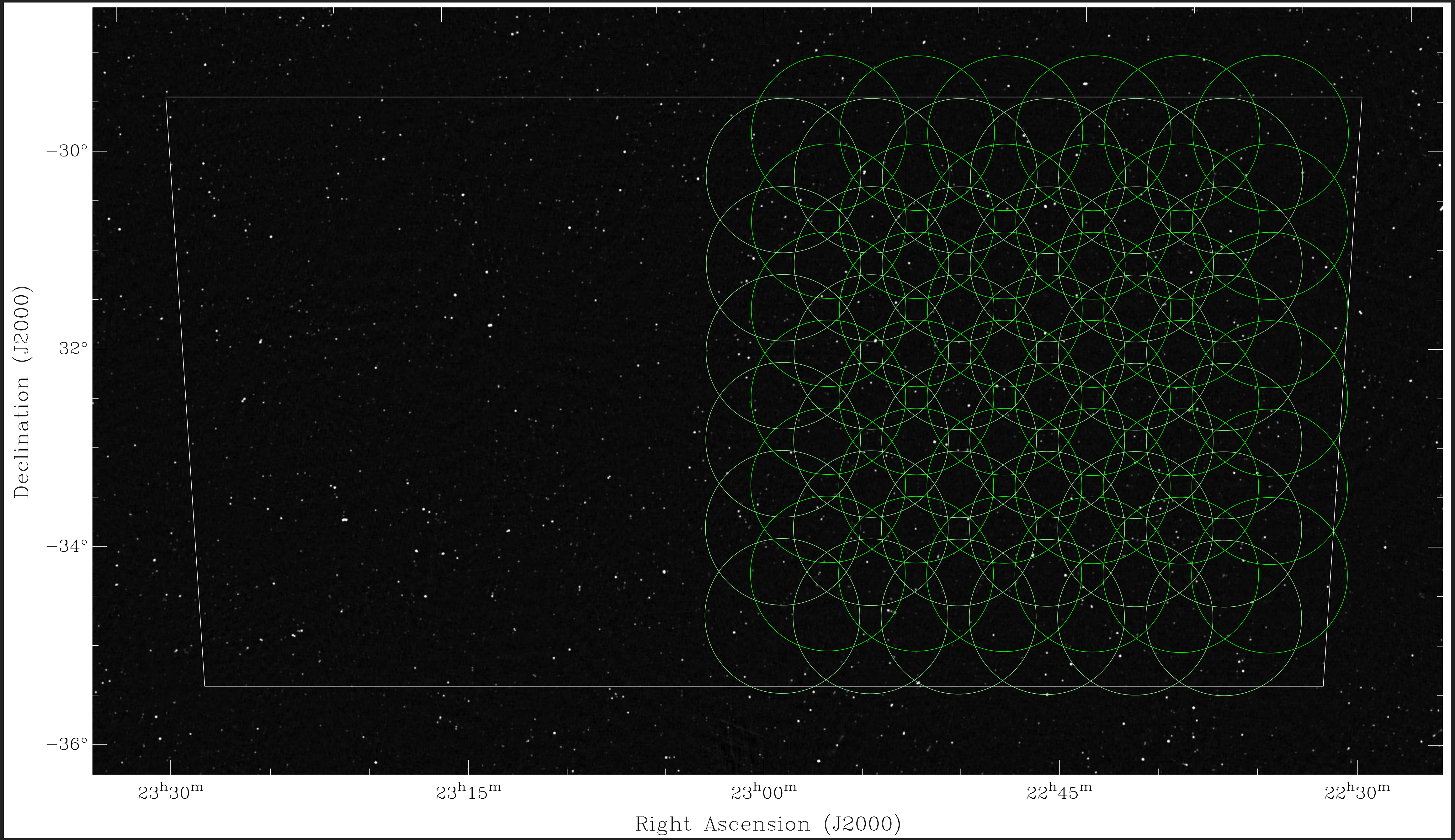
ASKAP OBSERVATIONS OF G23 FIELD

- 15-JAN-2018, 792.5 - 1032.5 MHz, 15 ant, 11 hrs



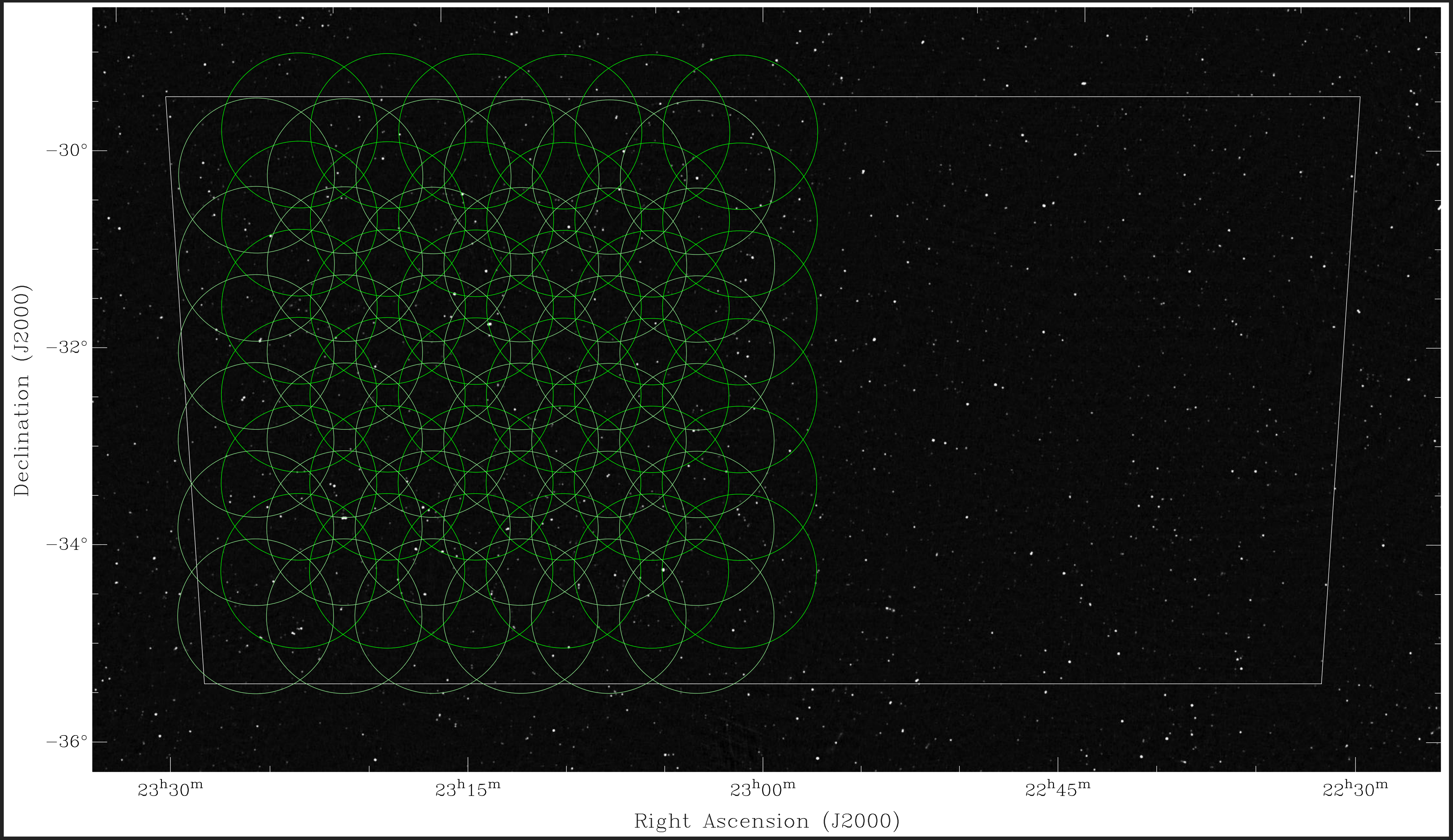
ASKAP OBSERVATIONS OF G23 FIELD

- 16-MAR-2018, 816.5 - 1056.5 MHz, 16 ant, 11 hrs



ASKAP OBSERVATIONS OF G23 FIELD

- 18-MAR-2018, 816.5 - 1056.5 MHz, 16 ant, 11 hrs



DATA PROCESSING – AUTOMATED PIPELINE

- Correlated data ingested from telescope to Pawsey Centre
- 11hrs with 16 antennas, 36 beams → 7.6 TB (!)
- Job scripts submitted on GALAXY or MAGNUS machines
- FLASH early pipeline written around MIRIAD tasks
- Philosophy based on reducing large data volume to 1D spectra and continuum images (~40GB from above)
- Future will use ASKAPsoft (general purpose pipeline)

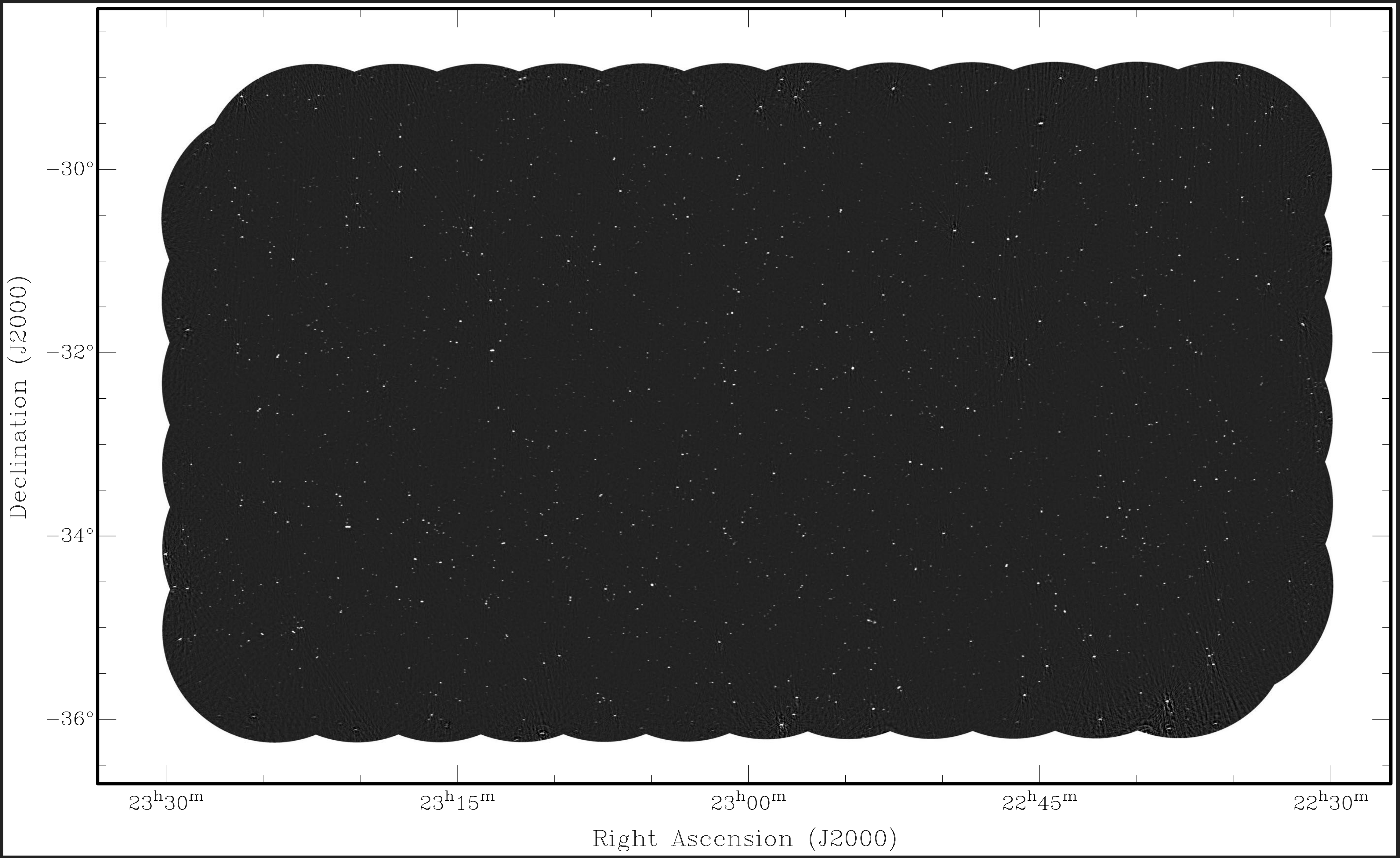
DATA PROCESSING – AUTOMATED PIPELINE

- Break processing down into (a) PAF beams and (b) band chunks
- Bandpass & initial gain calibration using 1934-638
- Self-calibration using (a) initial sky model from NVSS or SUMSS followed by (b) iterative self-calibration
- Two-step continuum subtraction in (u,v) plane using UVMODEL followed by UVLIN
- 1D spectra extracted from input catalogue of sources (same as NVSS/SUMSS sky model)

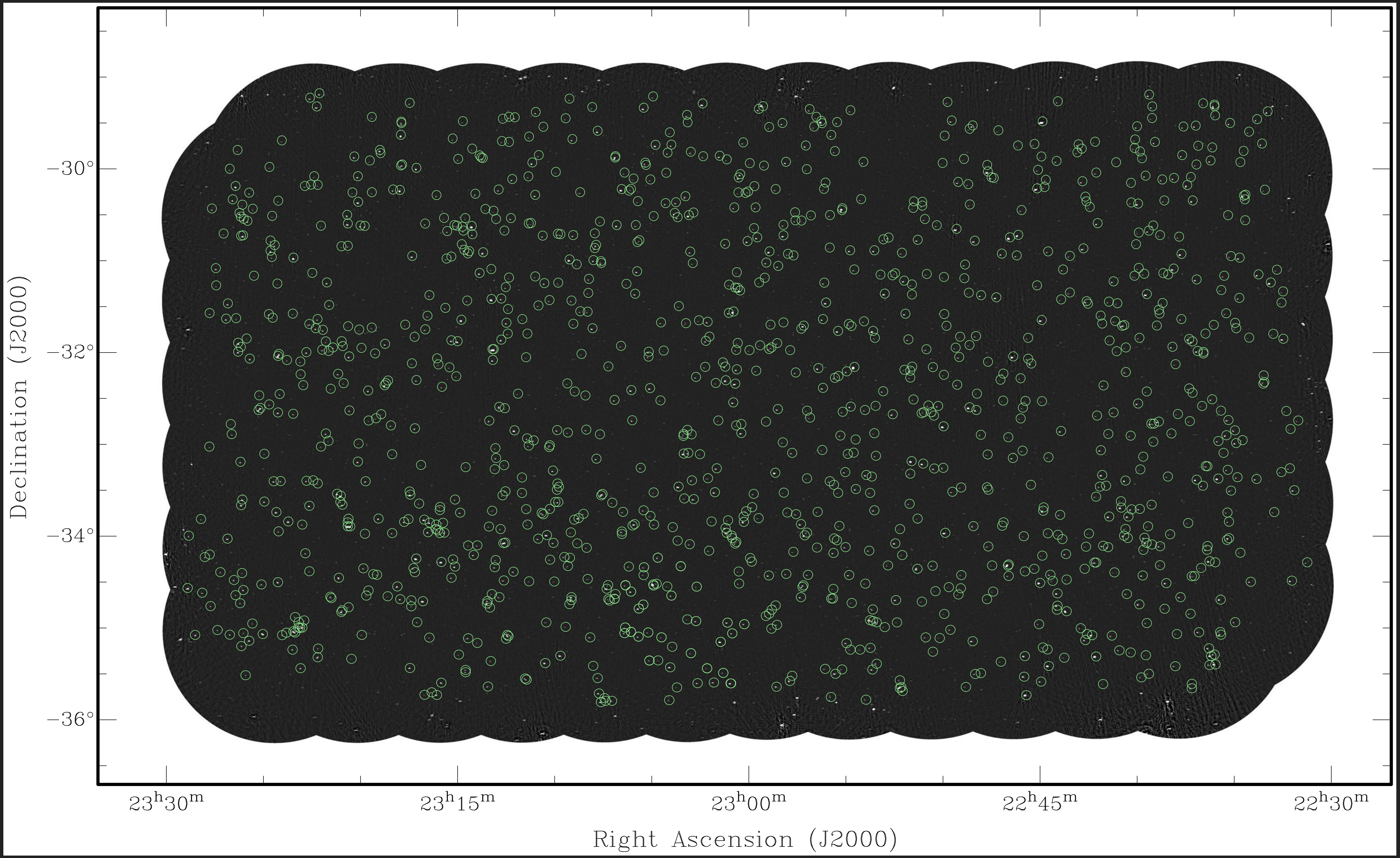
DATA PROCESSING - CHALLENGES

- Bandpass dominated by PAF beam forming intervals
  - (1) When smoothing solutions use break at each edge
  - (2) Use UVLIN to subtract out residuals (could subtract spectral line > interval size, 1MHz = 300km/s)
  - (3) On dish calibration source may solve this problem
- Wide field imaging (MIRIAD doesn't do well)
- Direction dependent calibration and bright source peeling

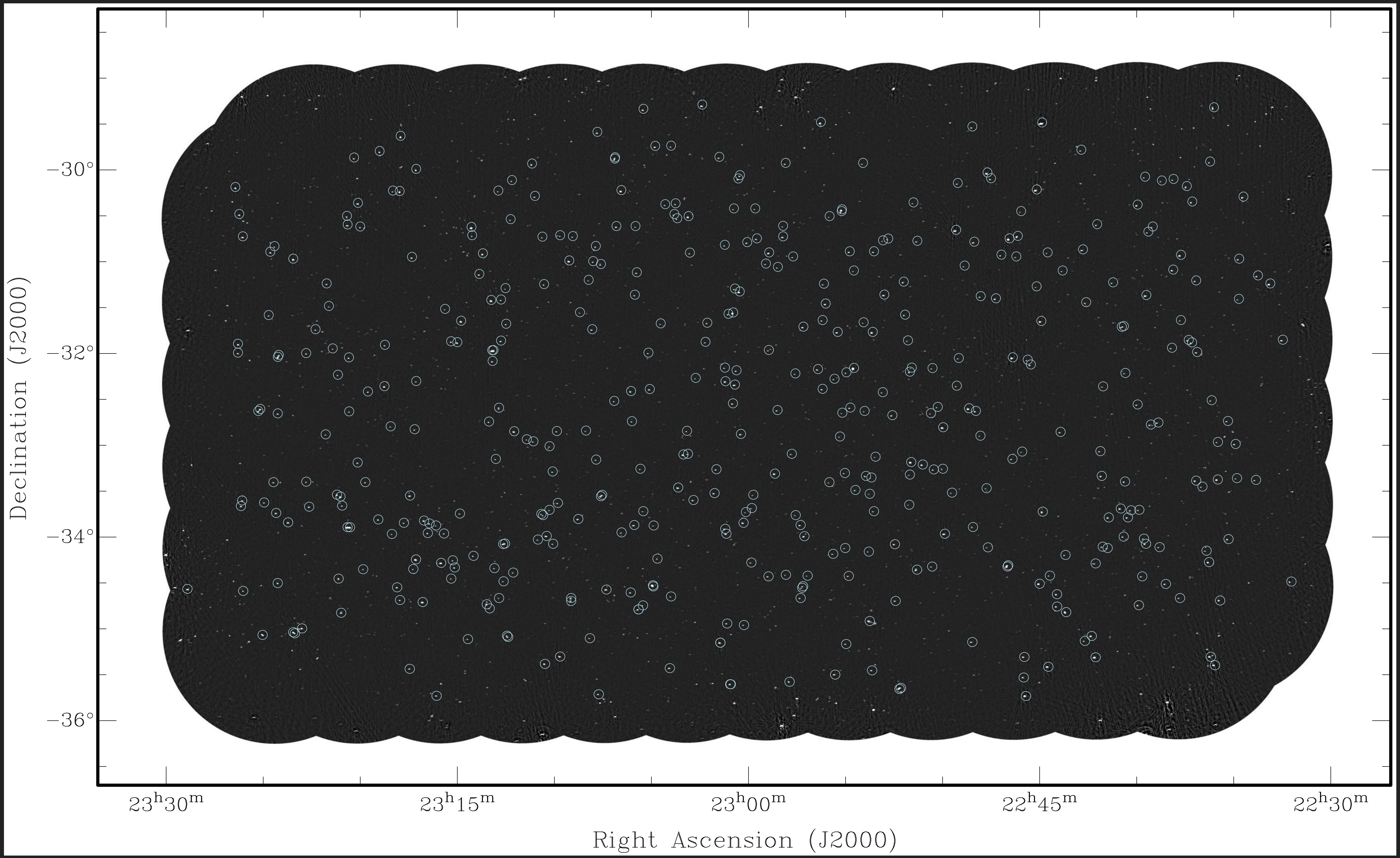
RESULTS – SOURCES



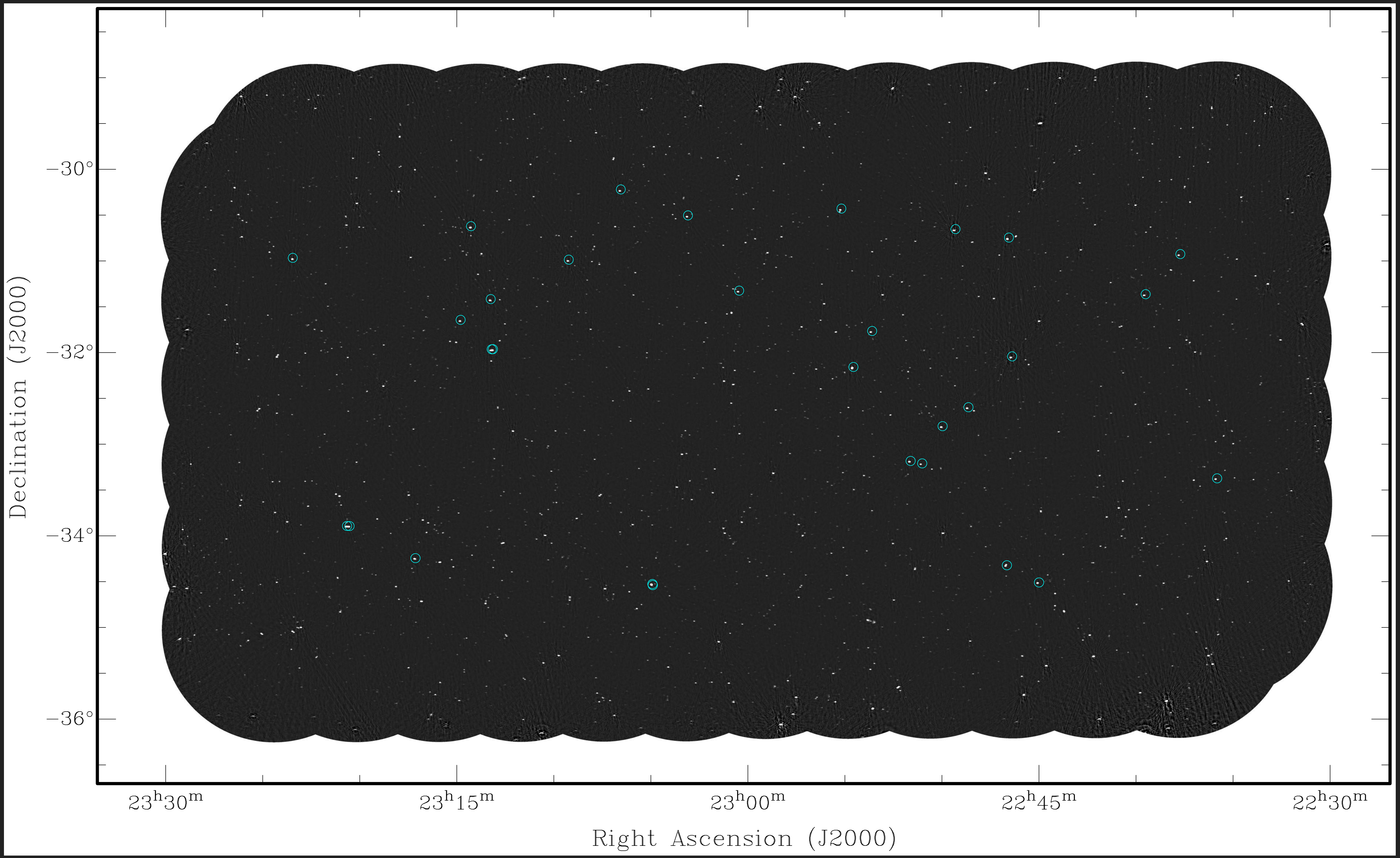
RESULTS – SOURCES ($\sigma_{ABS} < 100\%$ PER 18.5KHZ)



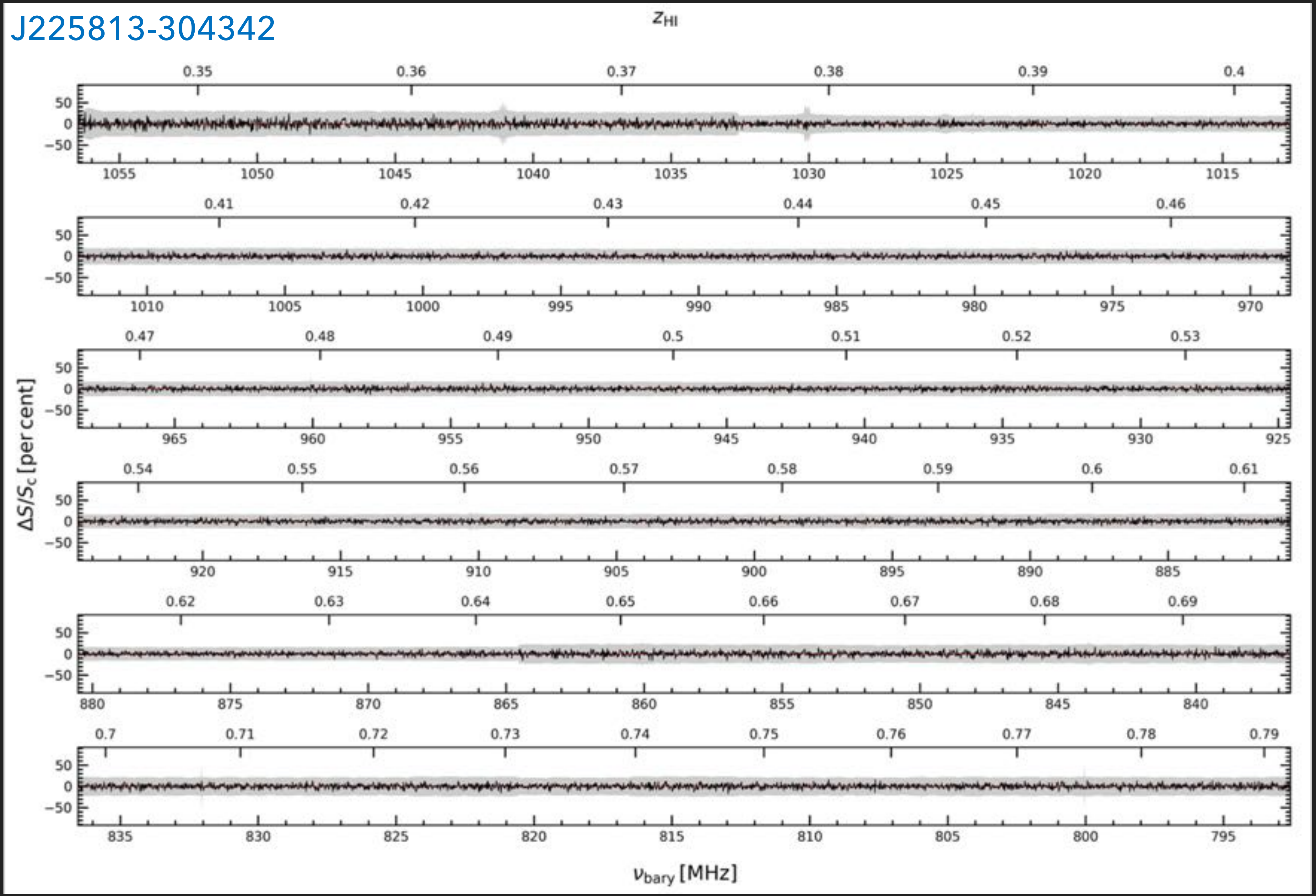
RESULTS – SOURCES ($\sigma_{ABS} < 10\%$ PER 18.5KHZ)



RESULTS – SOURCES ($\sigma_{ABS} < 1\%$ PER 18.5KHZ)

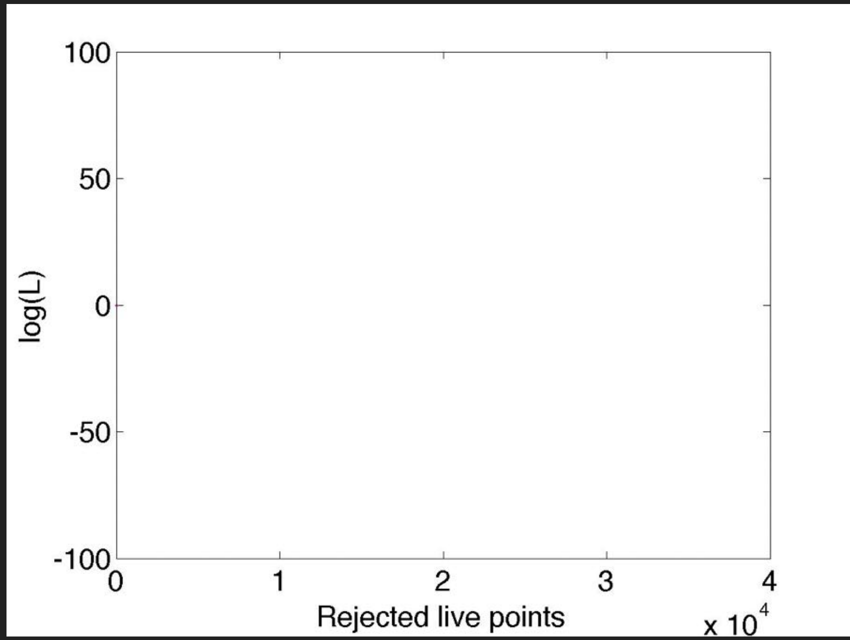


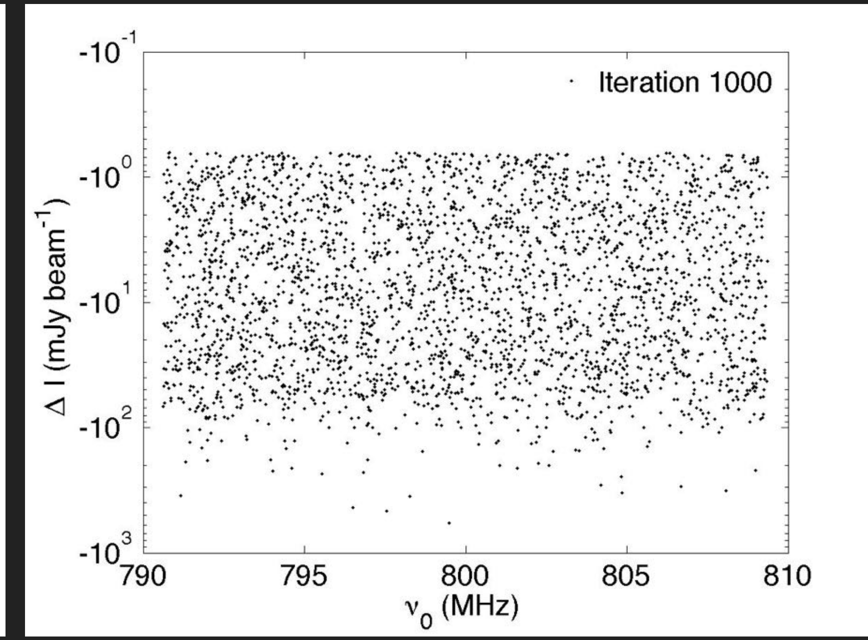
RESULTS - SPECTRA

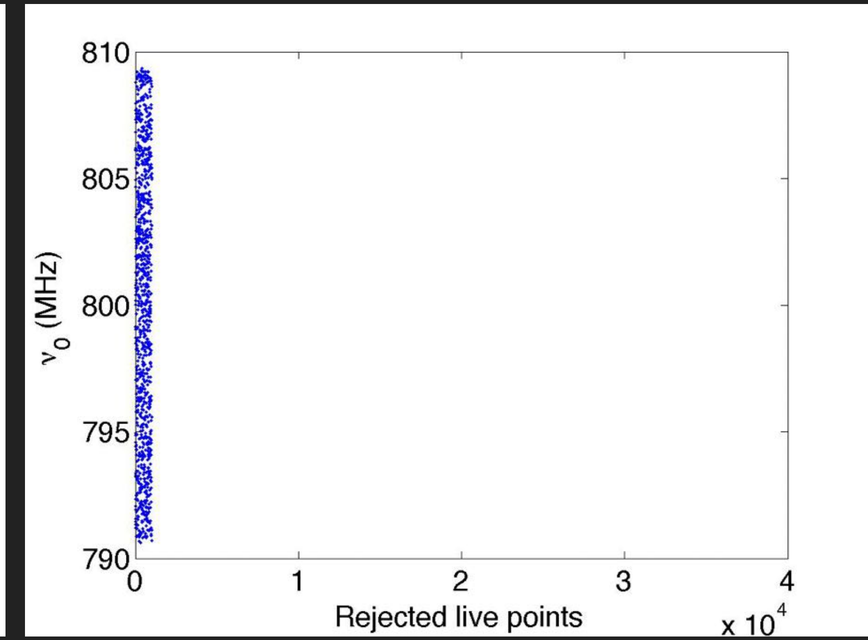


RESULTS – AUTOMATED LINE FINDING

- We adopt a forward modelling approach, testing for noise & line vs noise-only models using Bayesian methods (https://github.com/drjamesallison/flash_finder)
- We use multi-nested sampling (Feroz & Hobson) to find multiple lines







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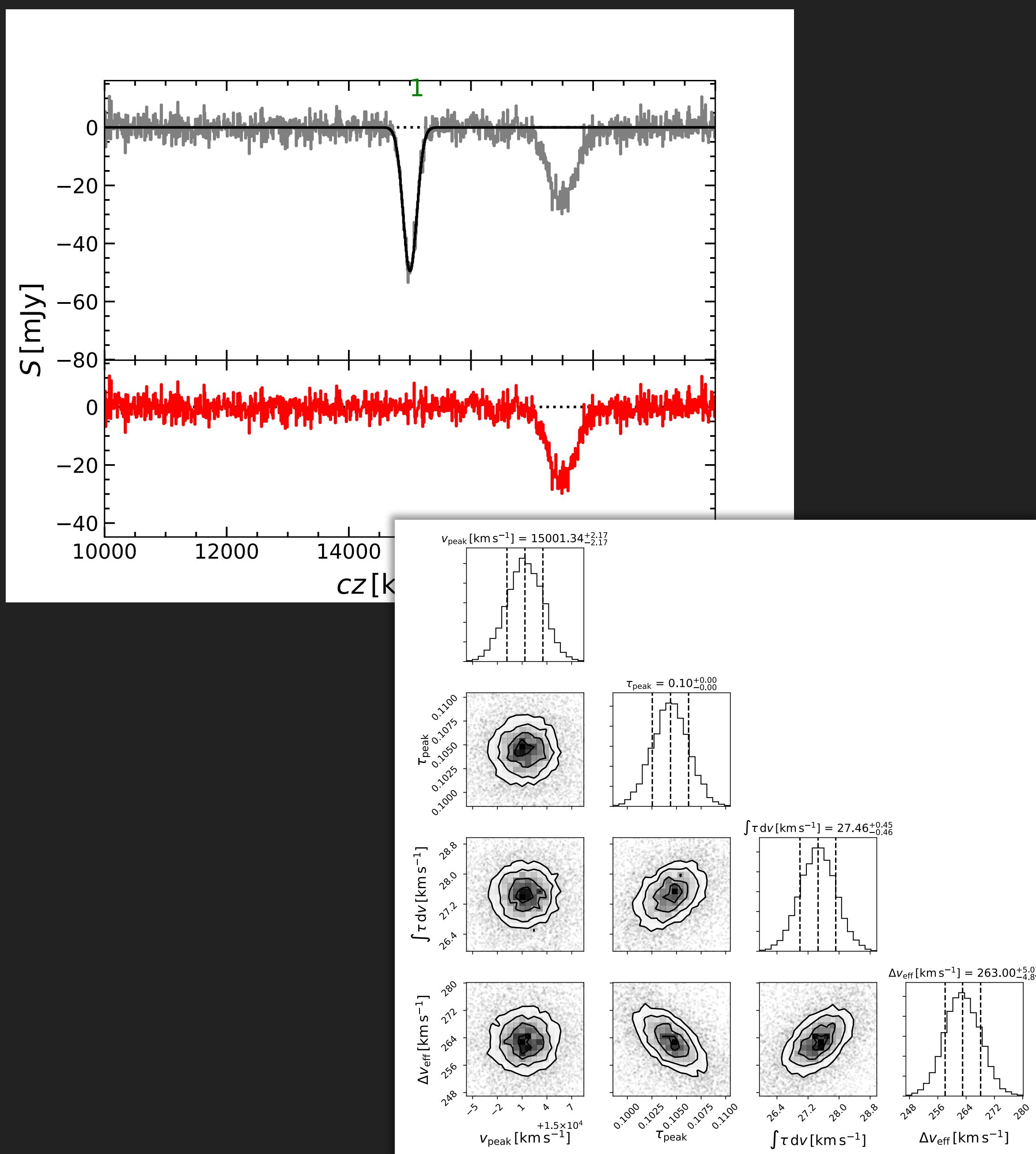
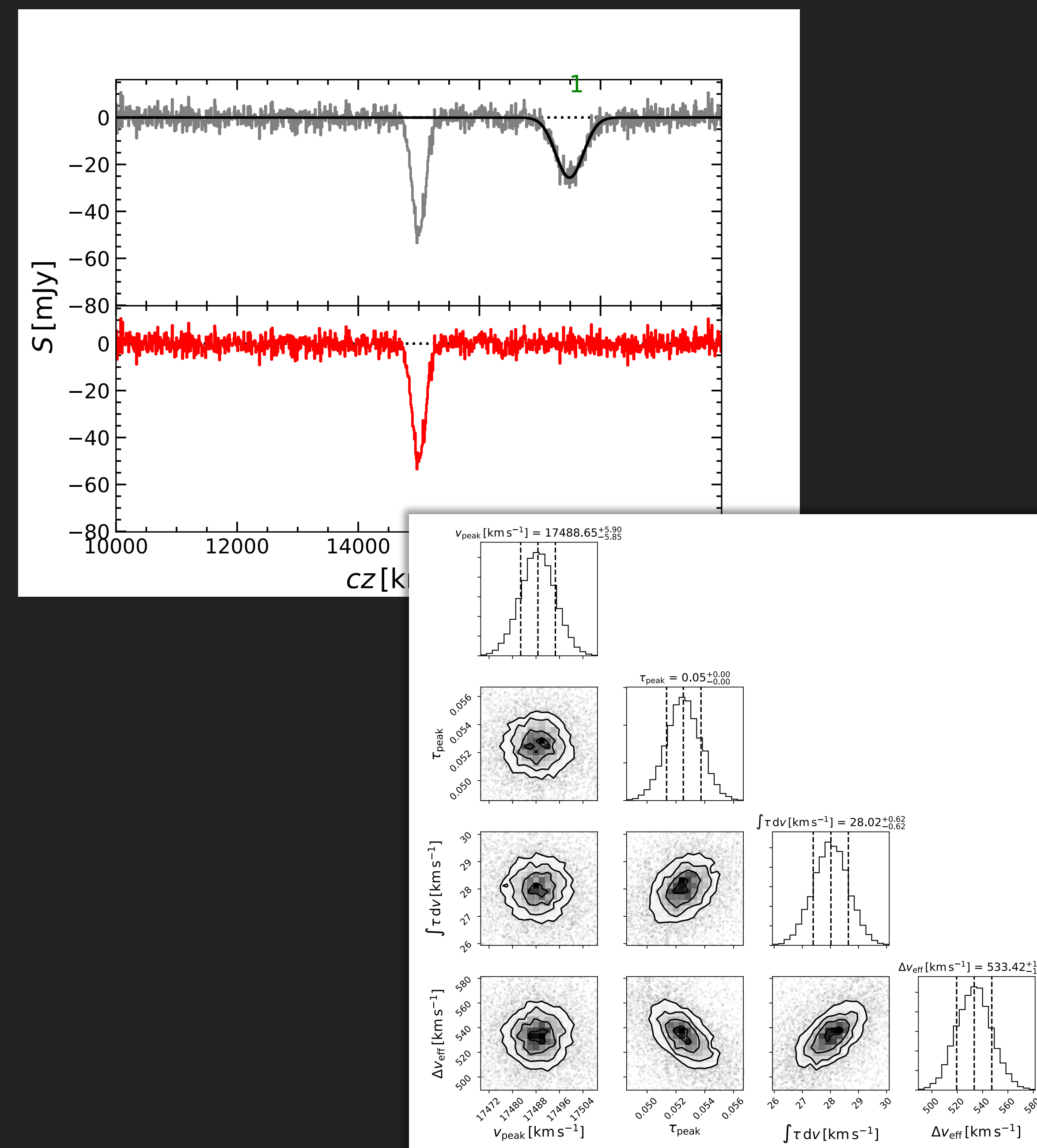
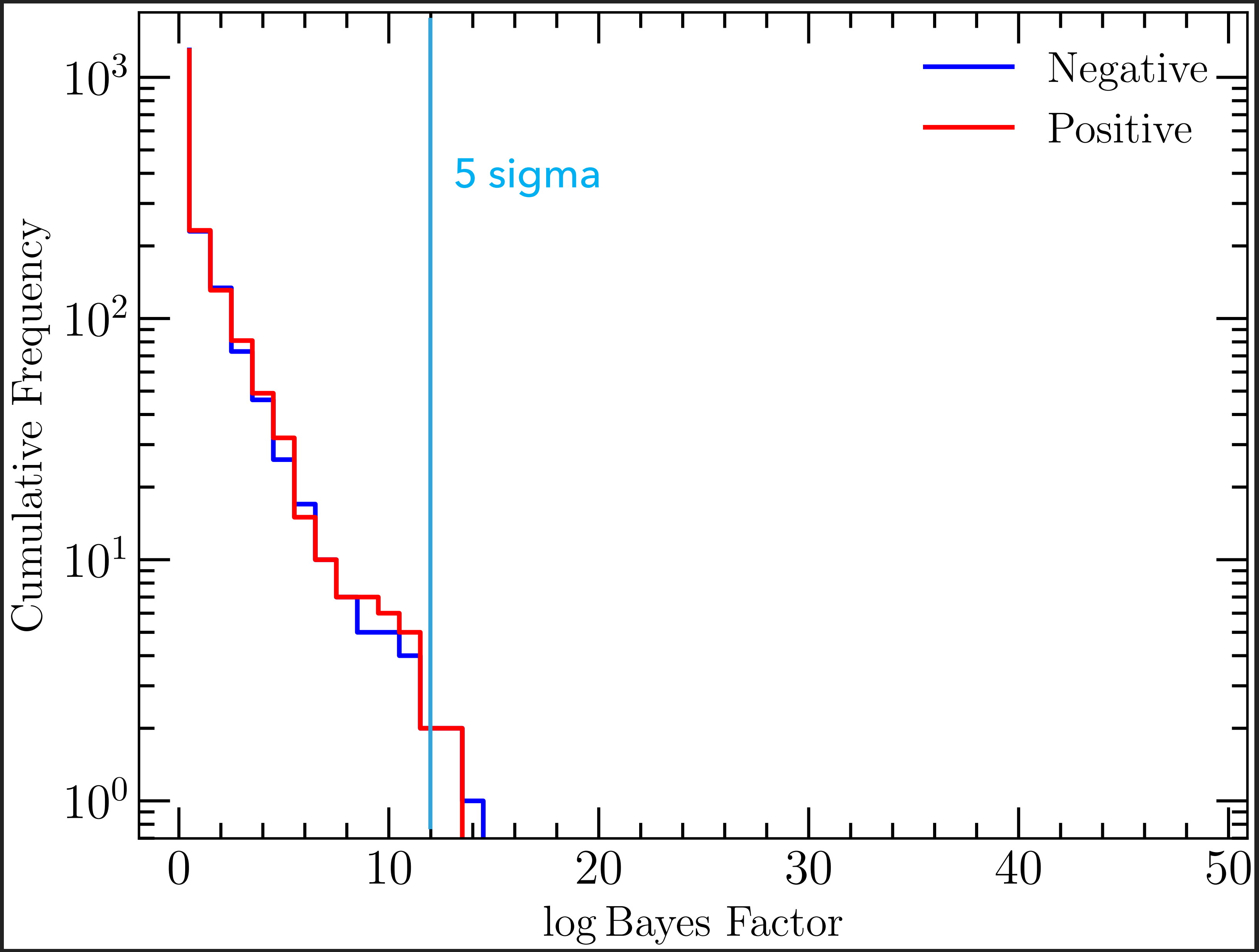




RESULTS – AUTOMATED LINE FINDING

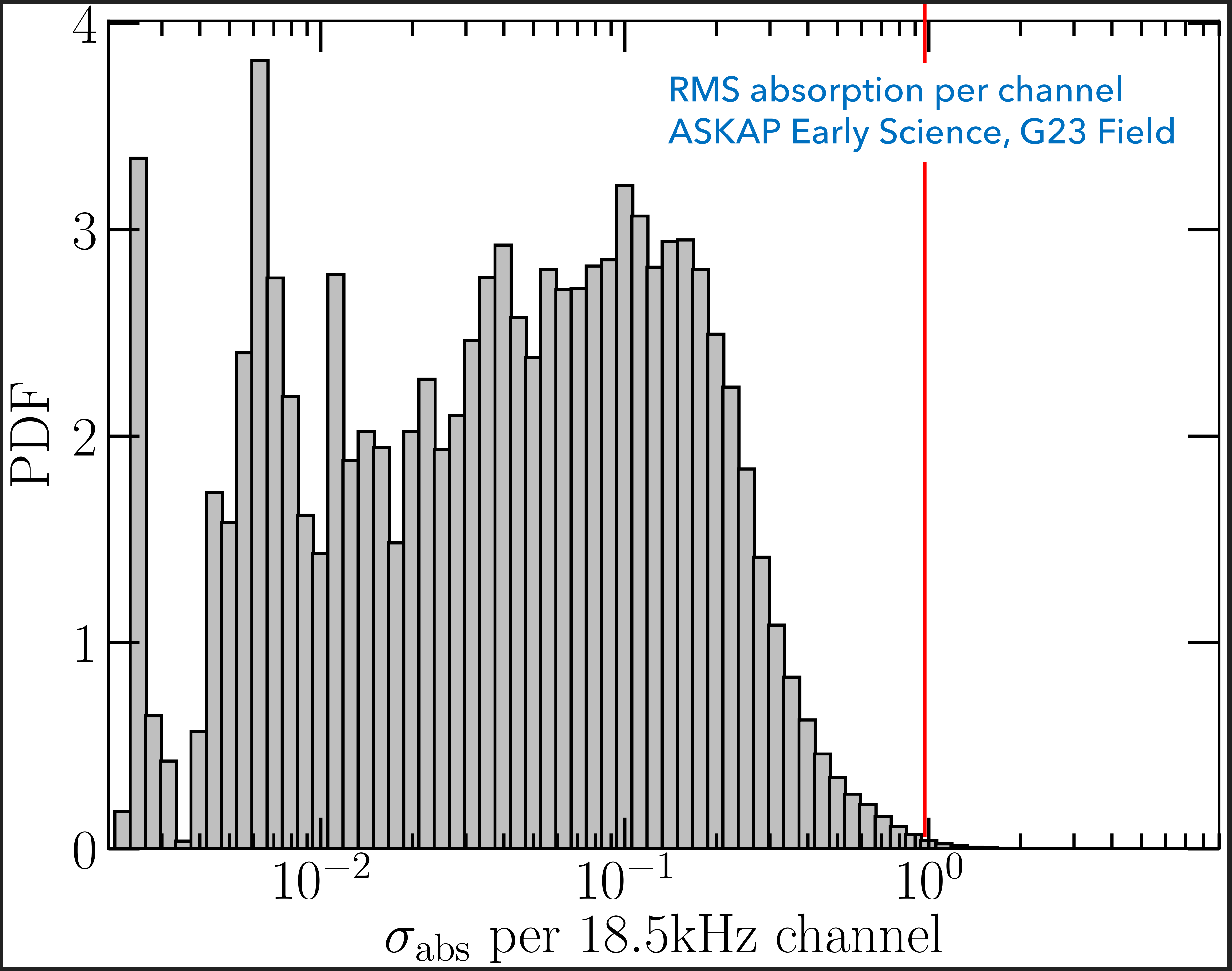
- Define reliability using positive line detections (Serra+ 12)



RESULTS - NOISE STATISTICS

- <RMS> ~ **5.9 +/- 0.5 mJy** per 18.5kHz per 5.5h per 16 ants
- Predict for FLASH → 4 mJy per 18.5kHz per 2h per 36 ants
  - 50% higher than original FLASH proposal
  - Consistent with theoretical noise predicted from T_{sys}/efficiency measurements by Chippendale + 15

RESULTS – NOISE STATISTICS



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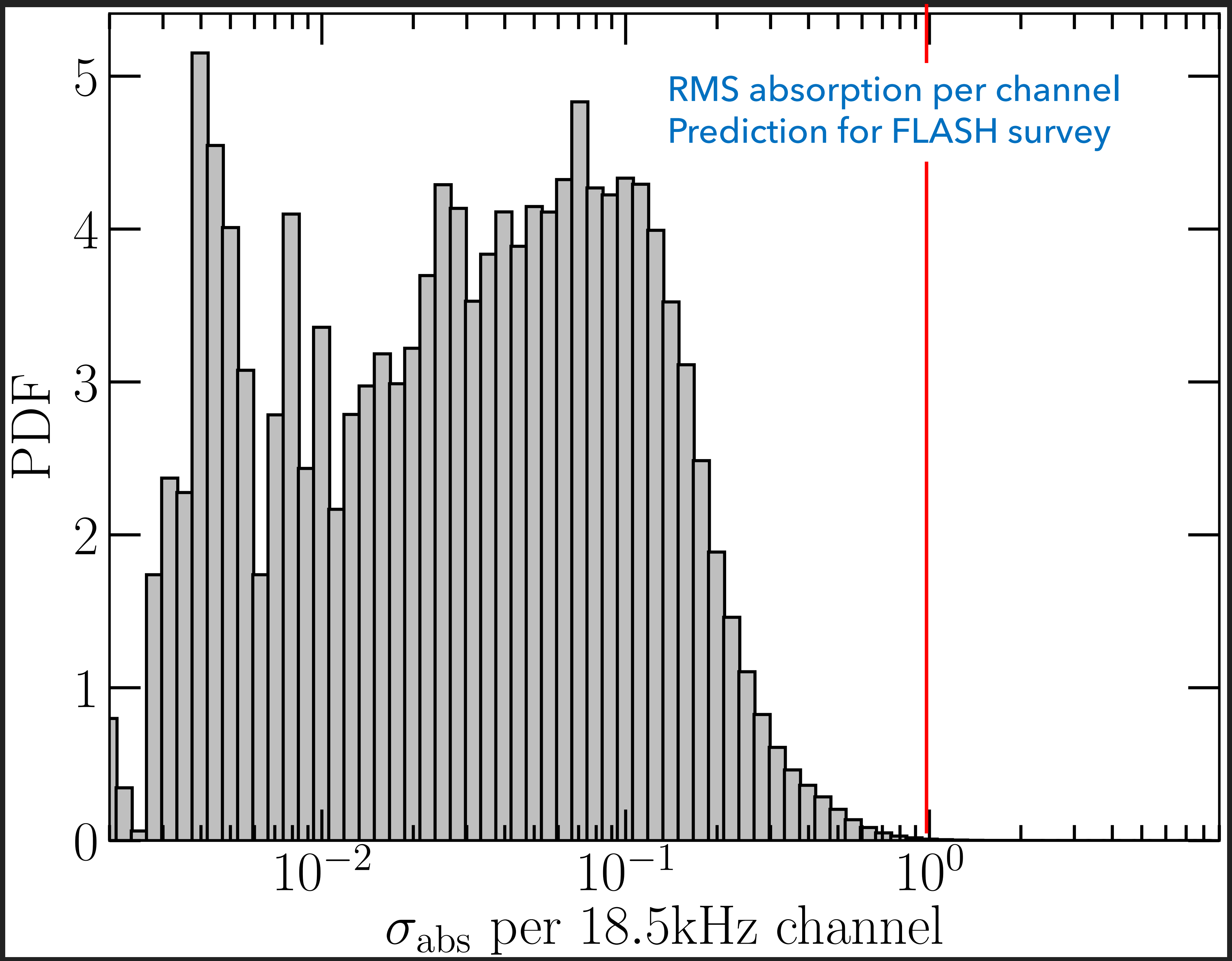
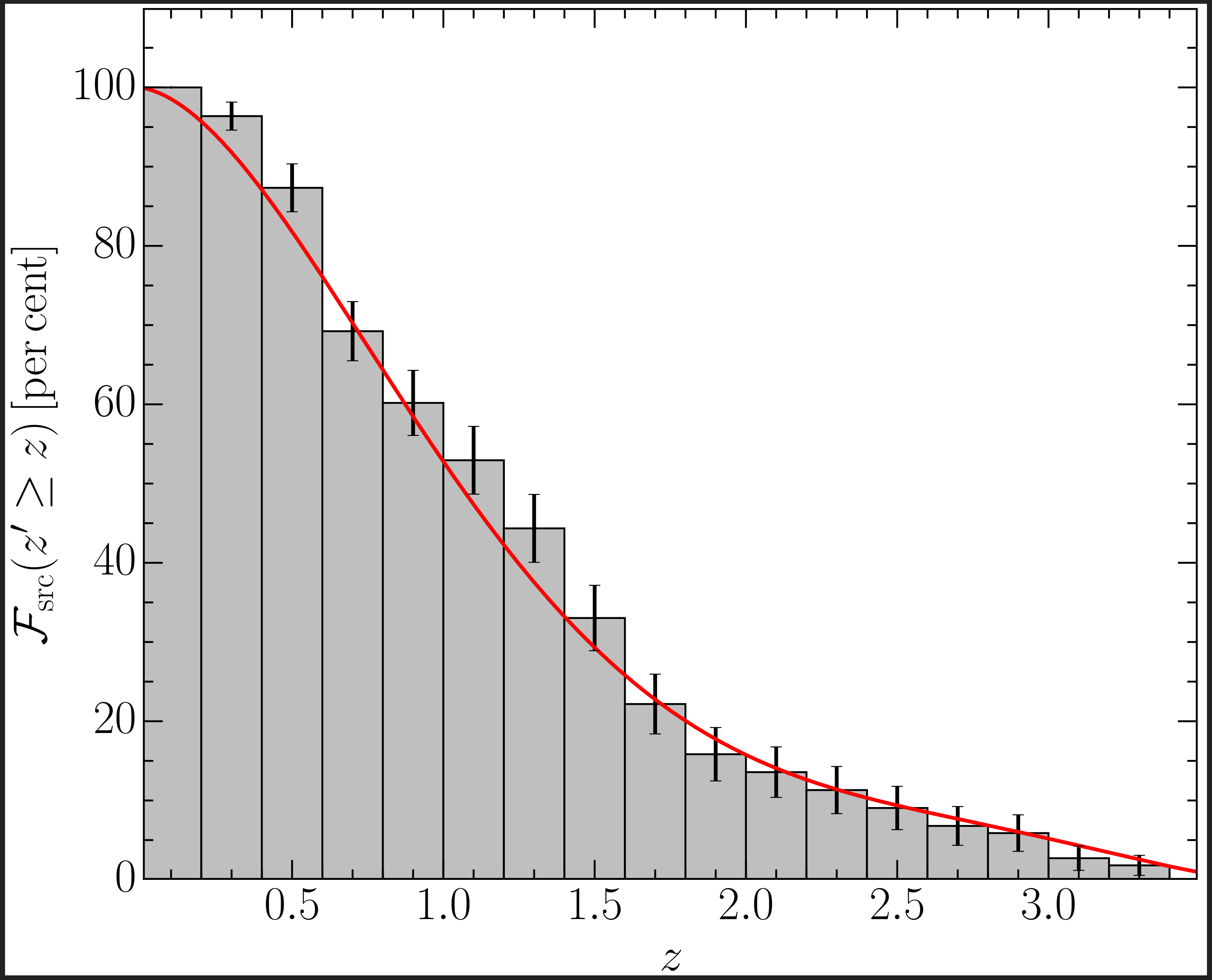
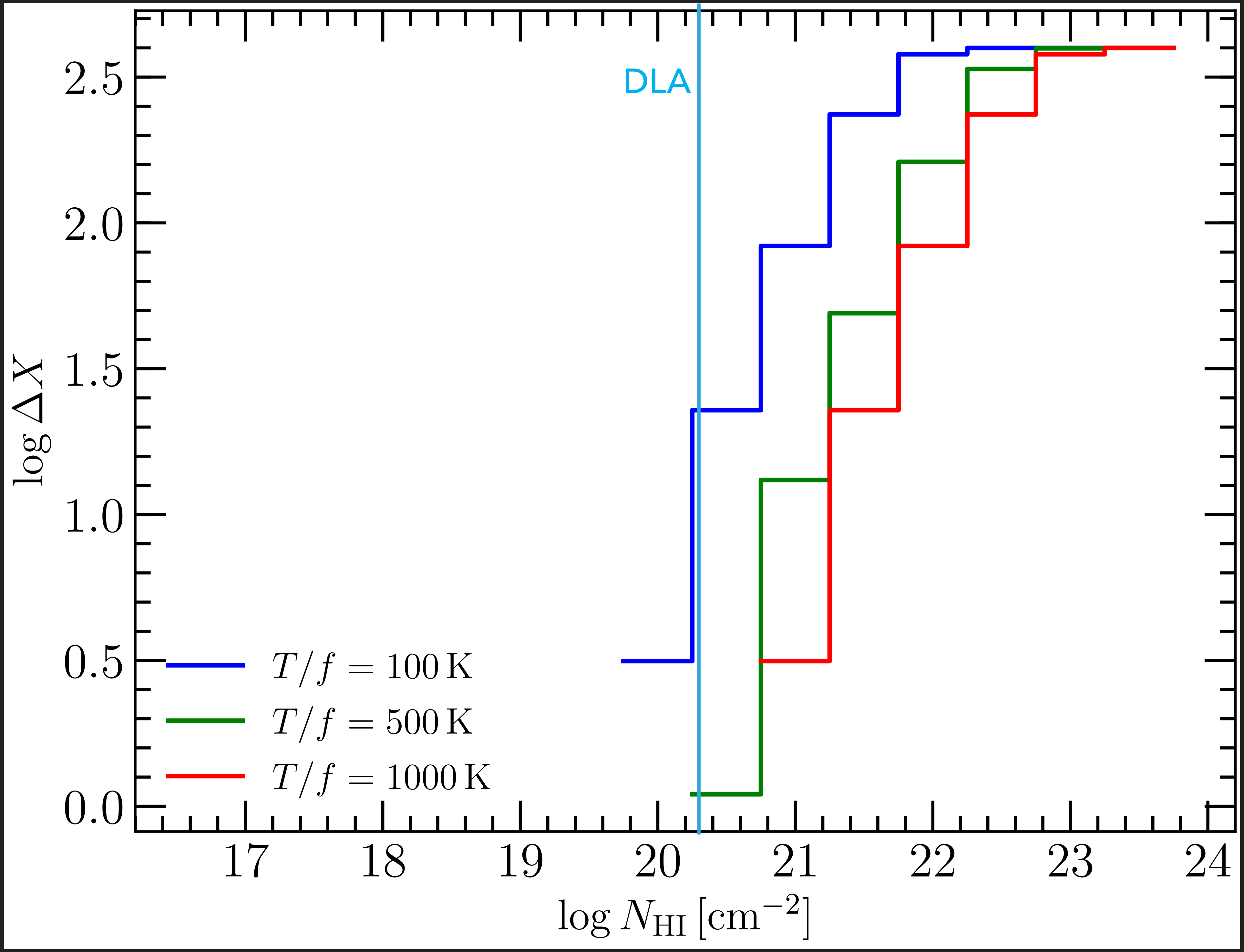


RESULTS – SOURCE REDSHIFTS?

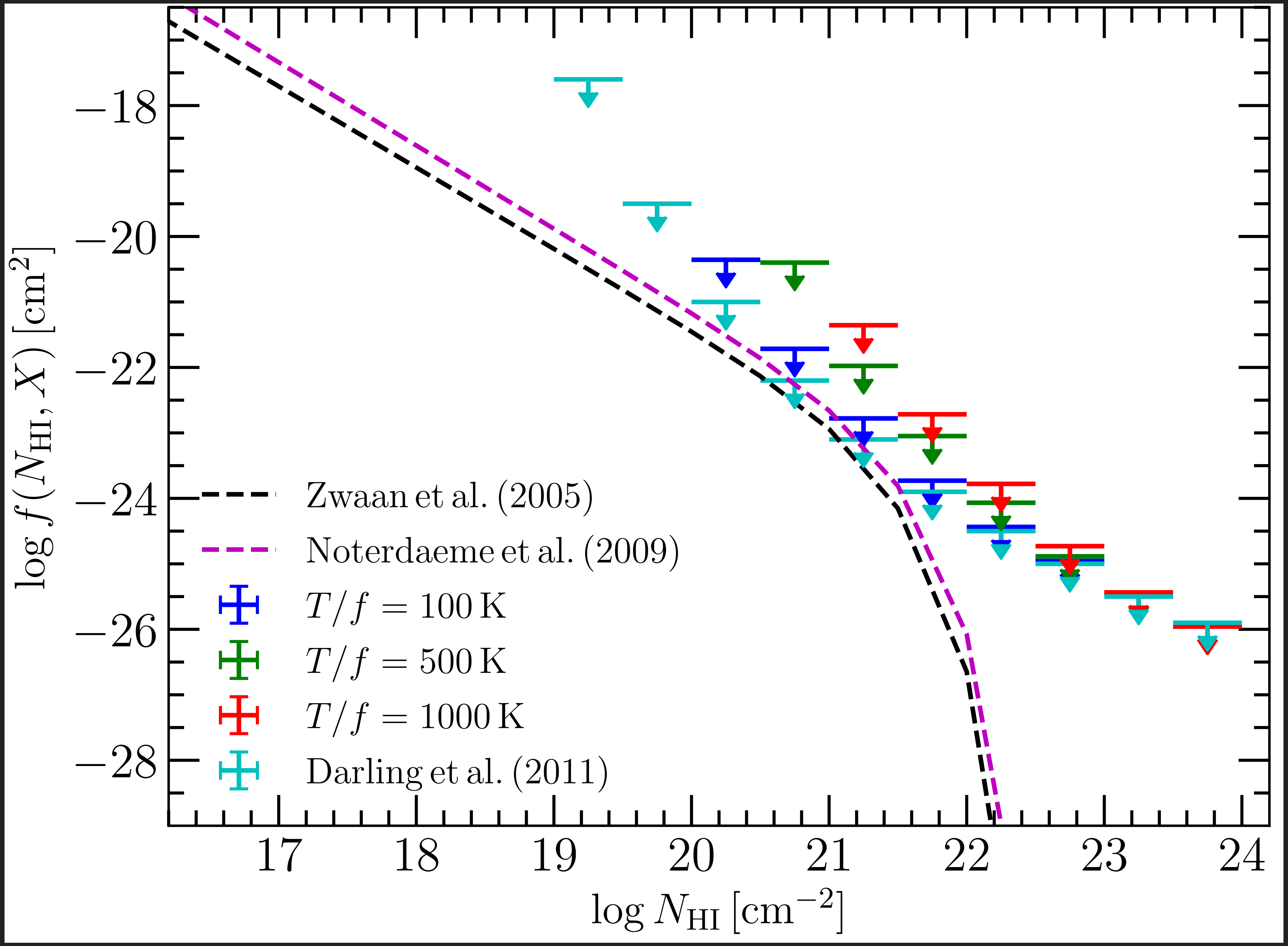
- G23 redshifts not yet fully public
- Let's use a statistical distribution
- Deep CENSORS spectroscopic survey (Brookes + 08)
- Complete for sources brighter than ~ 10mJy



RESULTS – COLUMN DENSITY SENSITIVITY



RESULTS – COMPARISON WITH N_{HI} DISTRIBUTION



WHERE ARE ALL THE INTRINSIC ABSORBERS?

- ASKAP observations of GAMA23 give **30 sight lines** with <RMS> ~ 1 % per 18.5 kHz channel
- **30%** of sources brighter than 10mJy between z = 0.34 and 0.79 (e.g. Brookes + 08)
- No detections
- Consistent with rate ~10%
- Compare with targeted surveys (e.g. Maccagni+ 17)

CHALLENGES & FUTURE PROSPECTS

- Blind surveys for HI 21-cm absorption require large sky areas to obtain sufficient number of sensitive sight-lines
- These large data sets necessarily need fully automated methods of identifying & solving issues associated with instrumental errors
- In FLASH we now have an automated approach that we are fine tuning using ASKAP early science data
- Next step is FLASH pilot survey science covering ~ 1000 square degrees (~4% of survey)