ASTRON

Netherlands Institute for Radio Astronomy

LOFAR MSSS

Multifrequency Snapshot Sky Survey

Flux scale & spectral indices

George Heald (MSSS Project Leader)
(on behalf of the MSSS Team)

LSM, 01/10/2014

ASTRON is part of the Netherlands Organisation for Scientific Research (NWO)

LOFAR

MVF paper

- Now submitted to publication committee!
- MSSS team members providing last comments and adjustments
- Should be seen in Builders List soon…

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The LOFAR Multifrequency Snapshot Sky Survey (MSSS)

I. Survey description and first results

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ABSTRACT

We present the Multifrequency Snapshot Sky Survey (MSSS), the first northern-sky LOFAR imaging survey. In this introductory paper, we first describe in detail the motivation and design of the survey. Compared to previous radio surveys, MSSS is exceptional due to its intrinsic multifrequency nature providing information about the spectral properties of the detected sources over more than two octaves (from 30 to 160 MHz). The broadband frequency coverage, together with the fast survey speed generated by LOFAR's multibeaming capabilities, make MSSS the first survey of the sort anticipated to be carried out with the forthcoming Square Kilometre Array (SKA). Two of the sixteen frequency bands included in the survey were chosen to exactly overlap the frequency coverage of large-area Very Large Array (VLA) and Giant Metrewave Radio Telescope (GMRT) surveys at 74 MHz and 151 MHz respectively. The survey performance is illustrated within the "MSSS Verification Field" (MVF), a region of 100 square degrees centered at $(\alpha, \delta)_{J2000} = (15^h, 69°)$. The MSSS results from the MVF are compared with previous radio survey catalogs. We assess the flux and astrometric uncertainties in the catalog, as well as the completeness and reliability considering our source finding strategy. We determine the 90% completeness levels within the MVF to be 100 mJy at 135 MHz with 108″ resolution, and 550 mJy at 50 MHz with 166″ resolution. Images and catalogs for the full survey will be released to a public web server. We outline the plans for the ongoing production of the final survey products, and the ultimate public release of images and source catalogs.

Key words. Surveys — Radio continuum: general

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1. Background

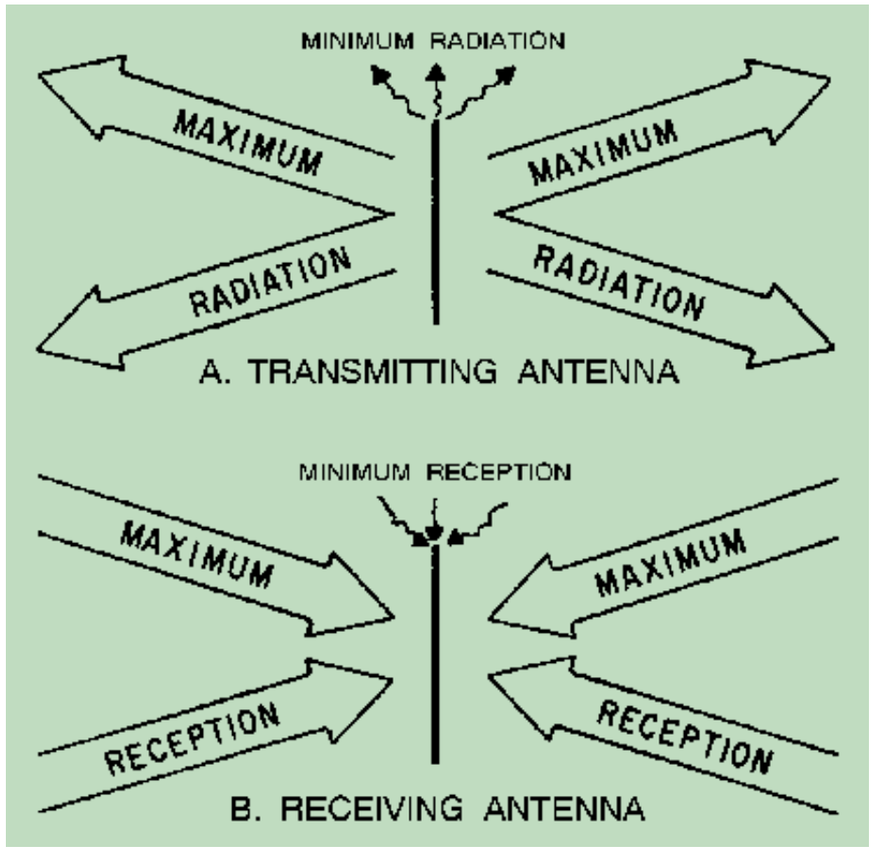
All-sky continuum surveys are a key application of radio telescopes. They provide the only unbiased view of galaxies in the

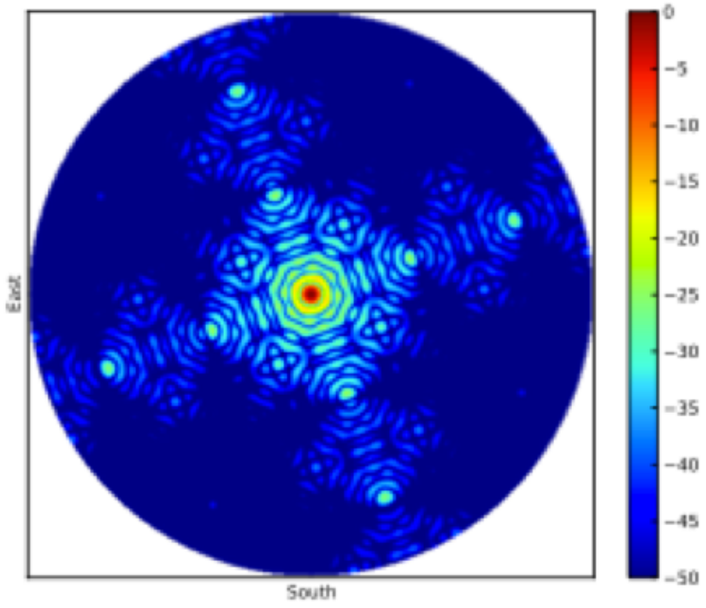
Continuing toward HBA catalog v1

- HBA mosaics under production (Alex Clarke; ~done)
  - After all images reconstructed following data deletion
- Catalog creation mechanism (Rene Breton; finished)
  - Now distinguishing properly between point sources and gaussians (using psf_vary module in pyBDSM; thanks to David Rafferty)
- Reprocessing routines nearly finished (Georgi Kokotanekov)

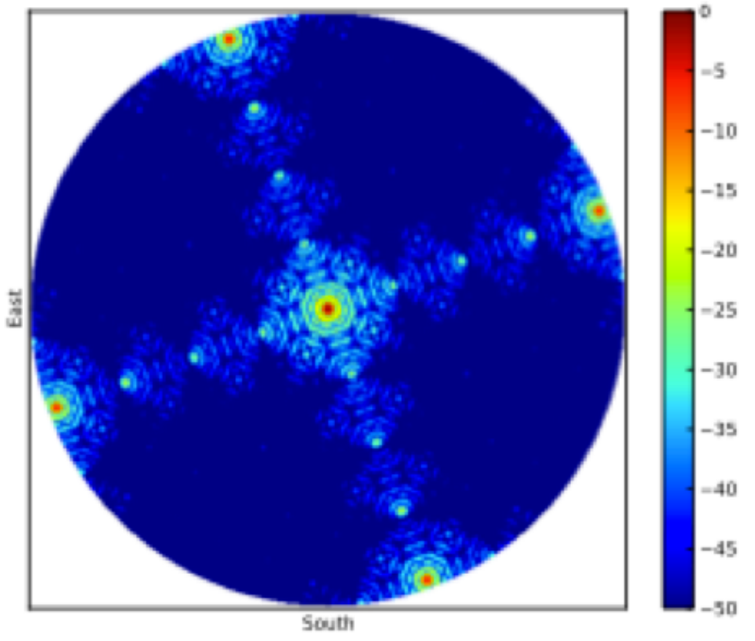
Unmodeled beam effects

- Aspects not included in standard beam model
  - power in grating lobes
  - mutual coupling
- These can lead to strong frequency dependent effects





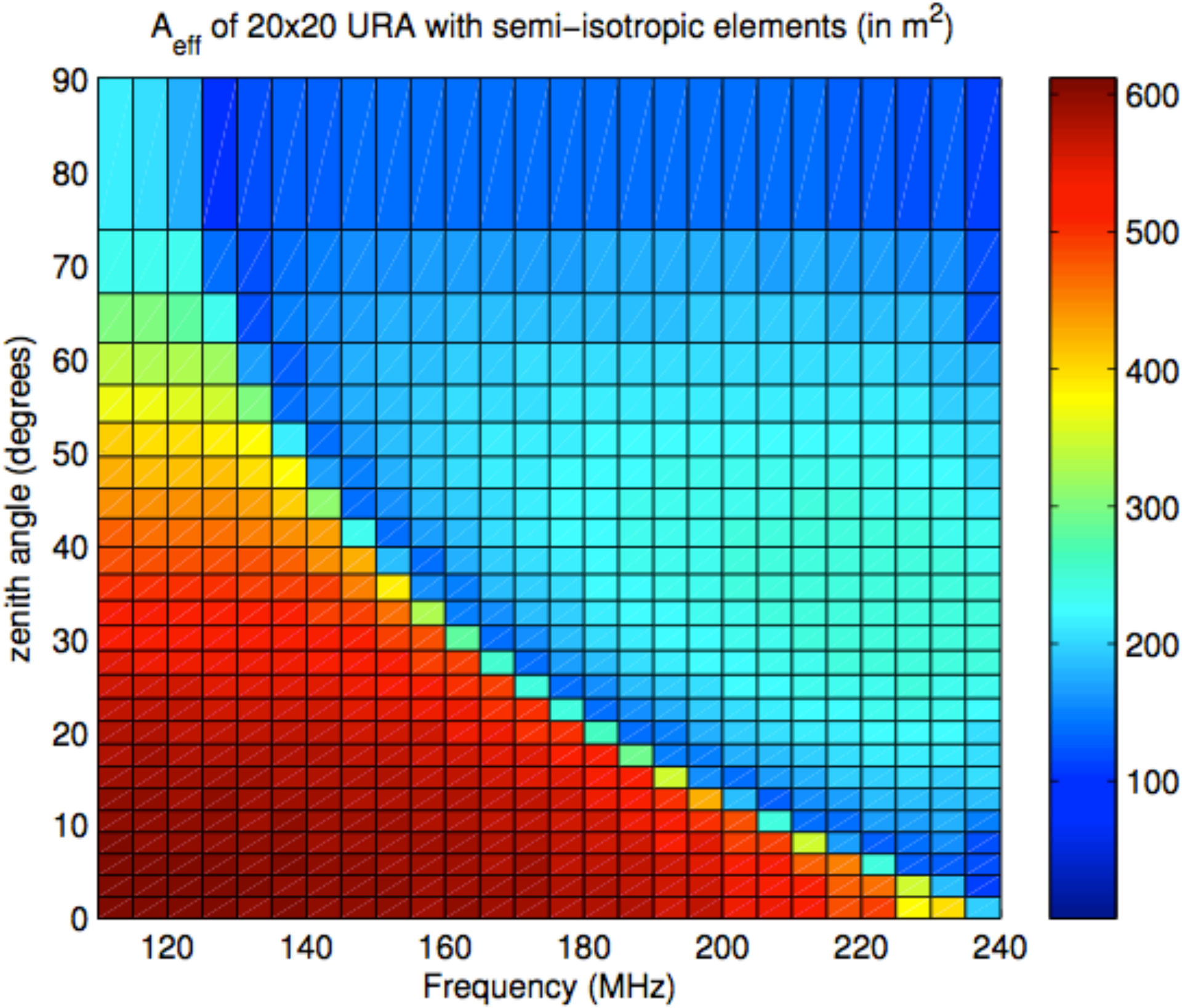
150 MHz



240 MHz

Beam images from Michiel Brentjens

- Related to issues identified by transient group?



From Arts, Kant, & Wijnholds, "Sensitivity Approximation for Regular Aperture Arrays"

Attempt to confirm this effect

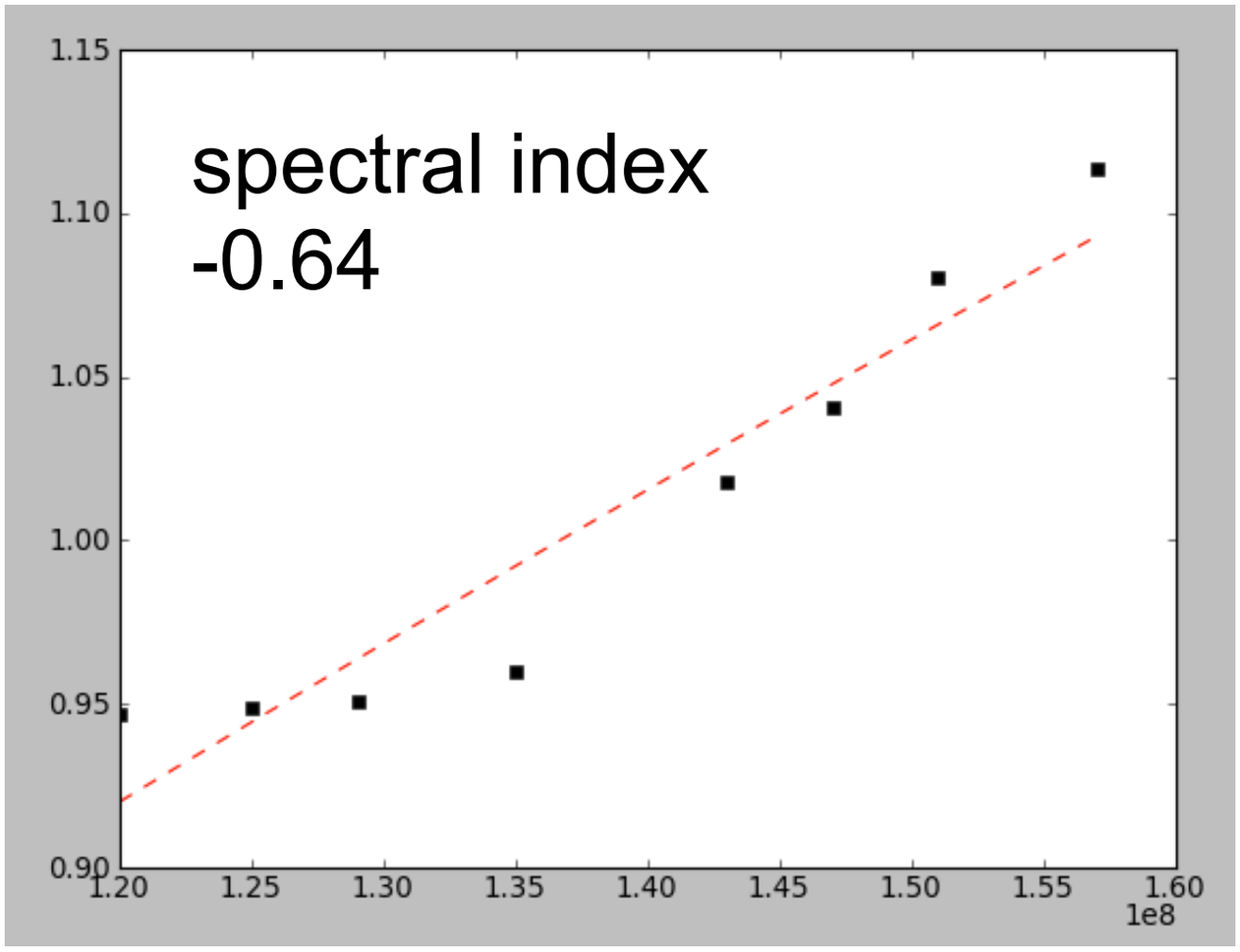
- Based initially from Stefan's MATLAB code to calculate the A_{eff} in a given direction & frequency, incorporating results of a full EM simulation by Michel Arts (all dipoles treated separately)
  - Simulations consider 3 different dipole angles, using symmetry and averaging to approximate the mean effect across the array
  - Used for pulsar flux density estimates in Coenen et al. (2014)
  - Includes mutual coupling & grating lobe attenuation
- Removed effect of element response as implemented in LOFAR beam software (using library written by Sarod Yatawatta)
- Considered each MSSS-HBA field separately, and the relative position of flux calibrator and target field, as a function of frequency
  - Used python interface to database behind msss.astron.nl, which provides observation times and calibrator IDs
- Calculated effective spectral index per MSSS-HBA field (average of 2 snapshots), applied on top of nominal average source spectral index 0.8

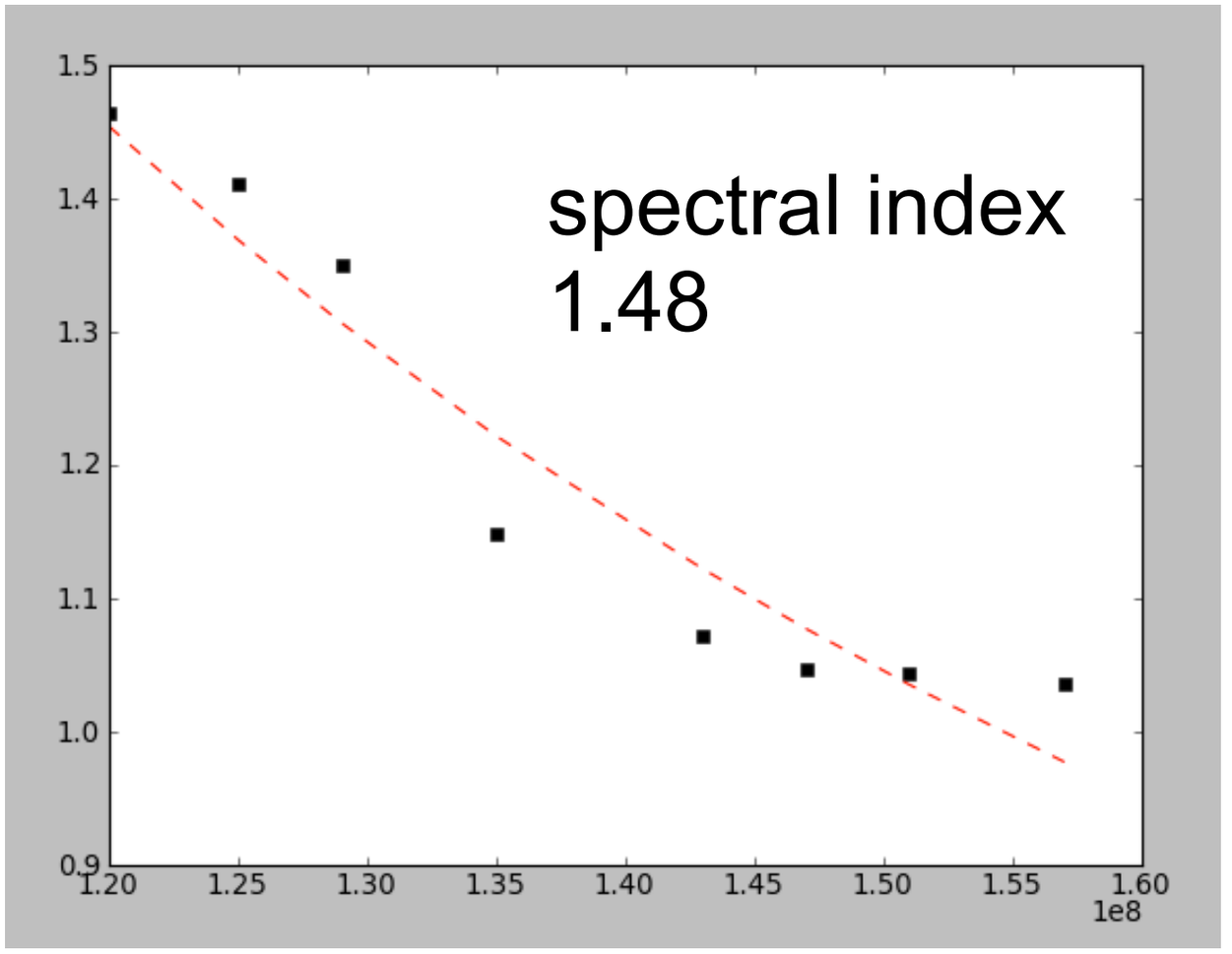
$$S'(\nu) = \frac{S_{\mathrm{t,SW}}(\nu)/S_{\mathrm{t,SY}}(\nu)}{S_{\mathrm{c,SW}}(\nu)/S_{\mathrm{c,SY}}(\nu)}$$

$$S \equiv |E_{00}E_{00}^*| + |E_{11}E_{11}^*|$$

−1.6 −0.8 0.0 0.8 1.6 2.4 3.2 4.0

Effective spectral index (modeled), assuming 0.8 intrinsic



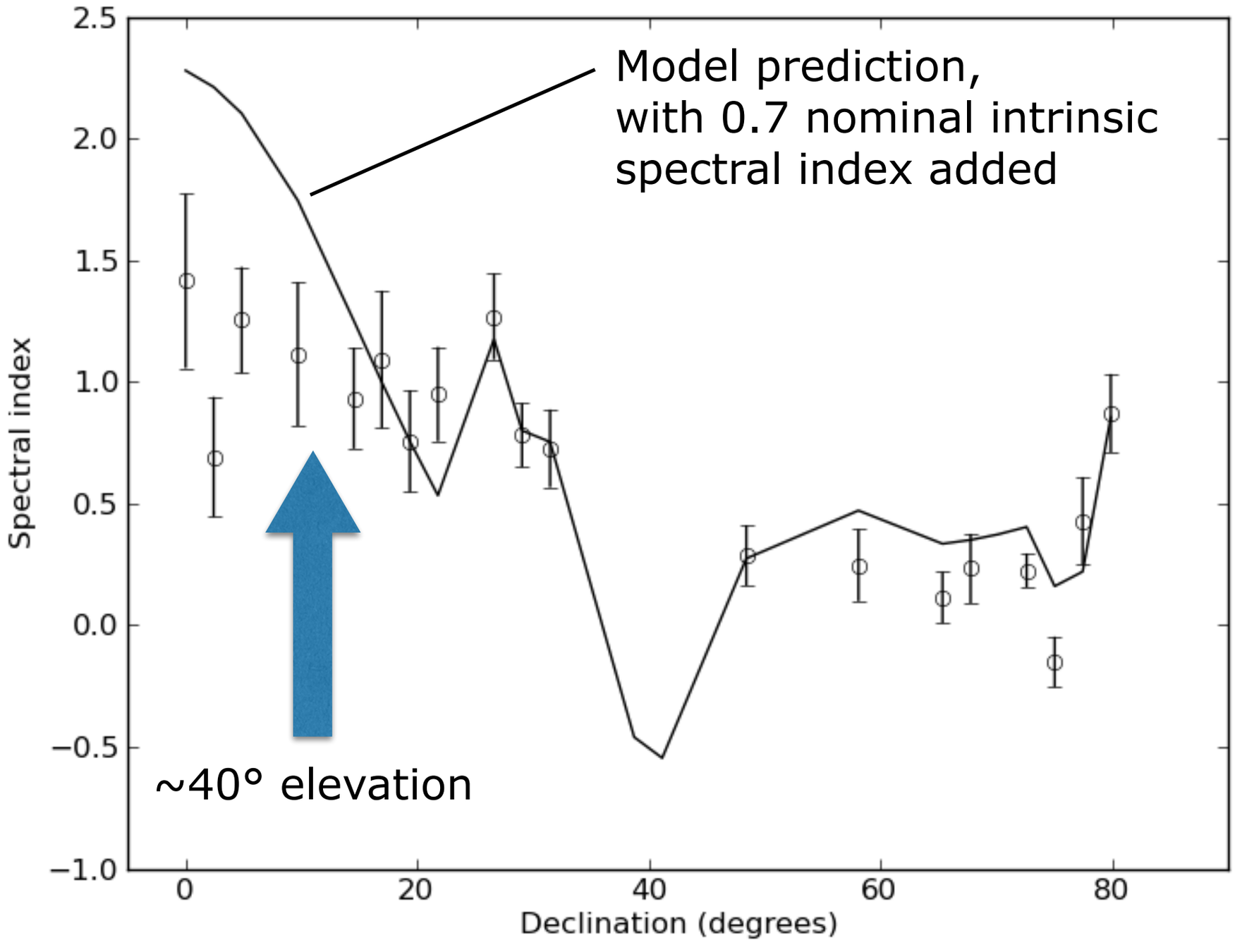


Things to note:

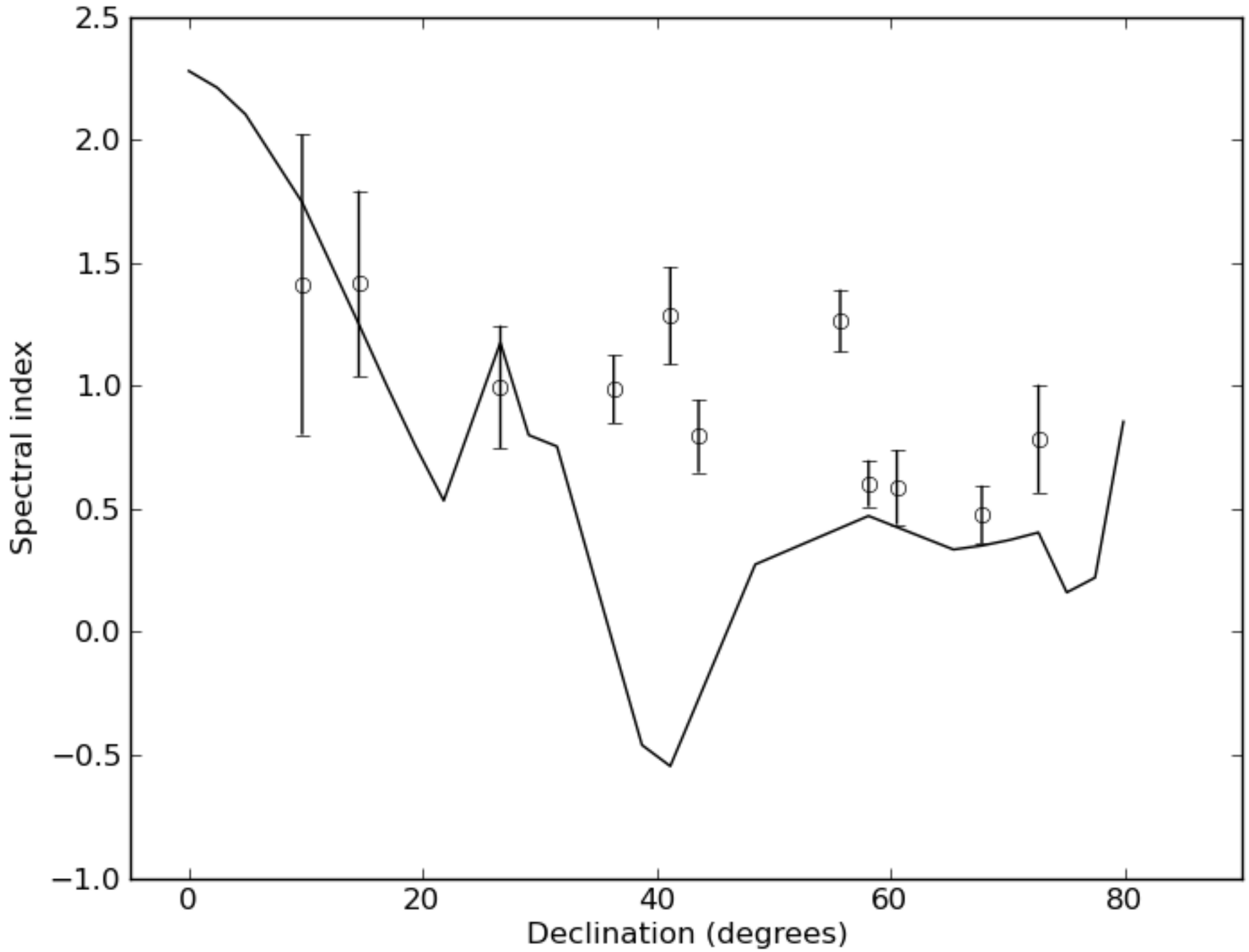
- At center of band (~140 MHz), ratio can often be ~1
- spectral structure more complicated than simple power law
- wide variation in behavior between different elevations

Stripe through RA=12h region

- Average source spectrum per MSSS-HBA field determined using script written by Martin Hardcastle

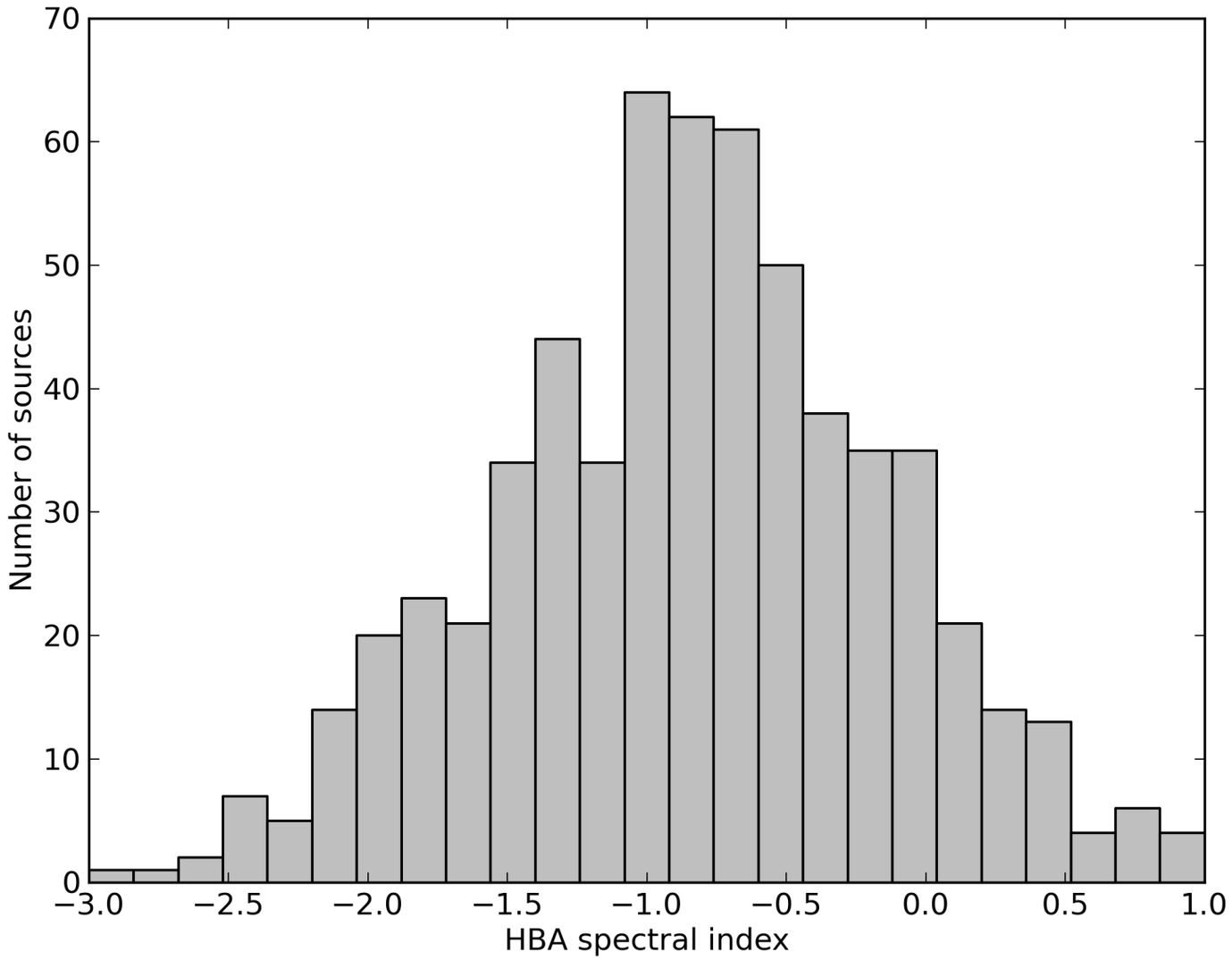


Stripe at RA=212d



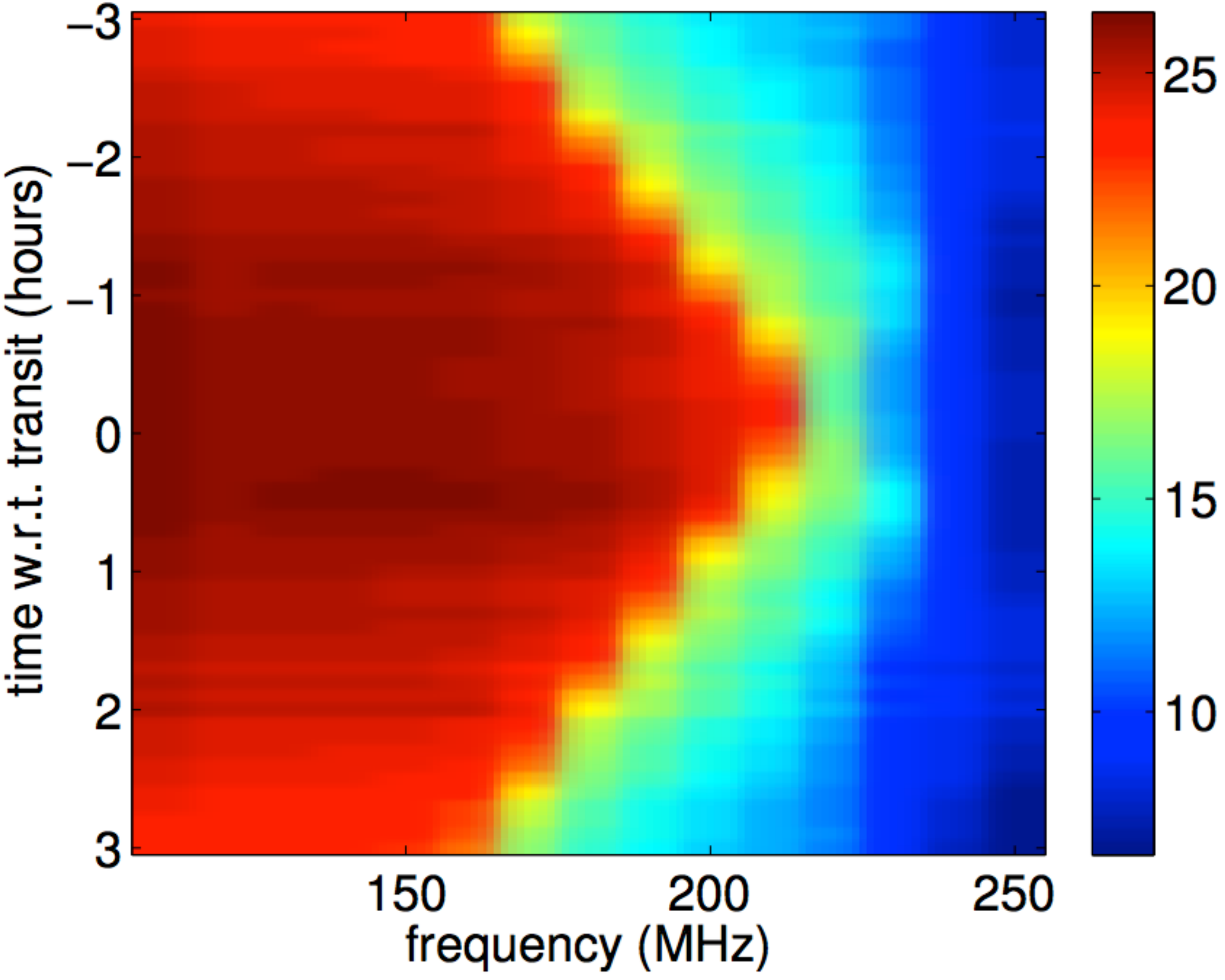
Effect on MVF

- Typical spectral index correction 0.2±0.2
- Effect of correcting HBA mosaics to be tested next
- Currently mean,median spectral index 0.78



Implications

- This effect may indeed explain the sometimes strange spectral index behavior that has been noted in LOFAR images
  - In principle this is completely predictable
- For MSSS, a frequency-dependent flux correction can be applied before cataloging and spectral index determination
  (To be confirmed - ongoing test by Martin Hardcastle)
  - Snapshot observing strategy is key here
- For longer track observations, this simple type of correction is probably not feasible due to time variability of the effect
  - Requires a correction at a deeper level in the LOFAR processing chain (implementation in the beam model would be ideal)
  - Only a small correction expected when primary calibrator is very close to target field



From Arts, Kant, & Wijnholds, "Sensitivity Approximation for Regular Aperture Arrays"

Next steps / suggestions / thoughts

- Further MSSS comparison and correction tests (~ all sky)
- Test with calibrator sequences, e.g. LC1_014 (Scaife et al)
- Investigate application in beam model directly (efficiency?)
- Generalize script presented here to judge average effect in long-track observations
  - Implement script to create instrument table incorporating this effect? Could then be applied by BBS or NDPPP, in addition to or instead of element correction from standard beam model