Broadband Spectra with the Allen Telescope Array

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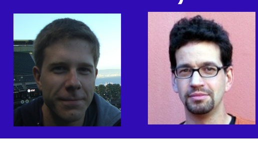

ABSTRACT

Continuous frequency coverage is an important scientific and technical goal of the Square Kilometer Array (SKA). We investigate one avenue of reaching this goal with data taken from the high-resolution, broadband correlator of the Allen Telescope Array (ATA). With a total frequency coverage of 0.5 to 11.2 GHz and 1024 channels in a spectral window 100 MHz wide, the ATA is an ideal exploratory instrument for this kind of science. We present observations of calibrators taken over a broad swath of the ATA's frequency range and show how the well-known spectral indices of these sources can be recovered. With this consistency check in hand, a few sample broadband spectra and images of more scientifically interesting targets are presented. Our experiments explore the continuous frequency performance of the ATA antennas, feeds, and receivers and also identify the limitations that radio frequency interference place on our ability to make images. Further observations of this kind at the ATA will yield not only intriguing standalone science results but also valuable knowledge about the developments needed to endow the SKA with a robust continuous frequency capability.

ACKNOWLEDGMENT

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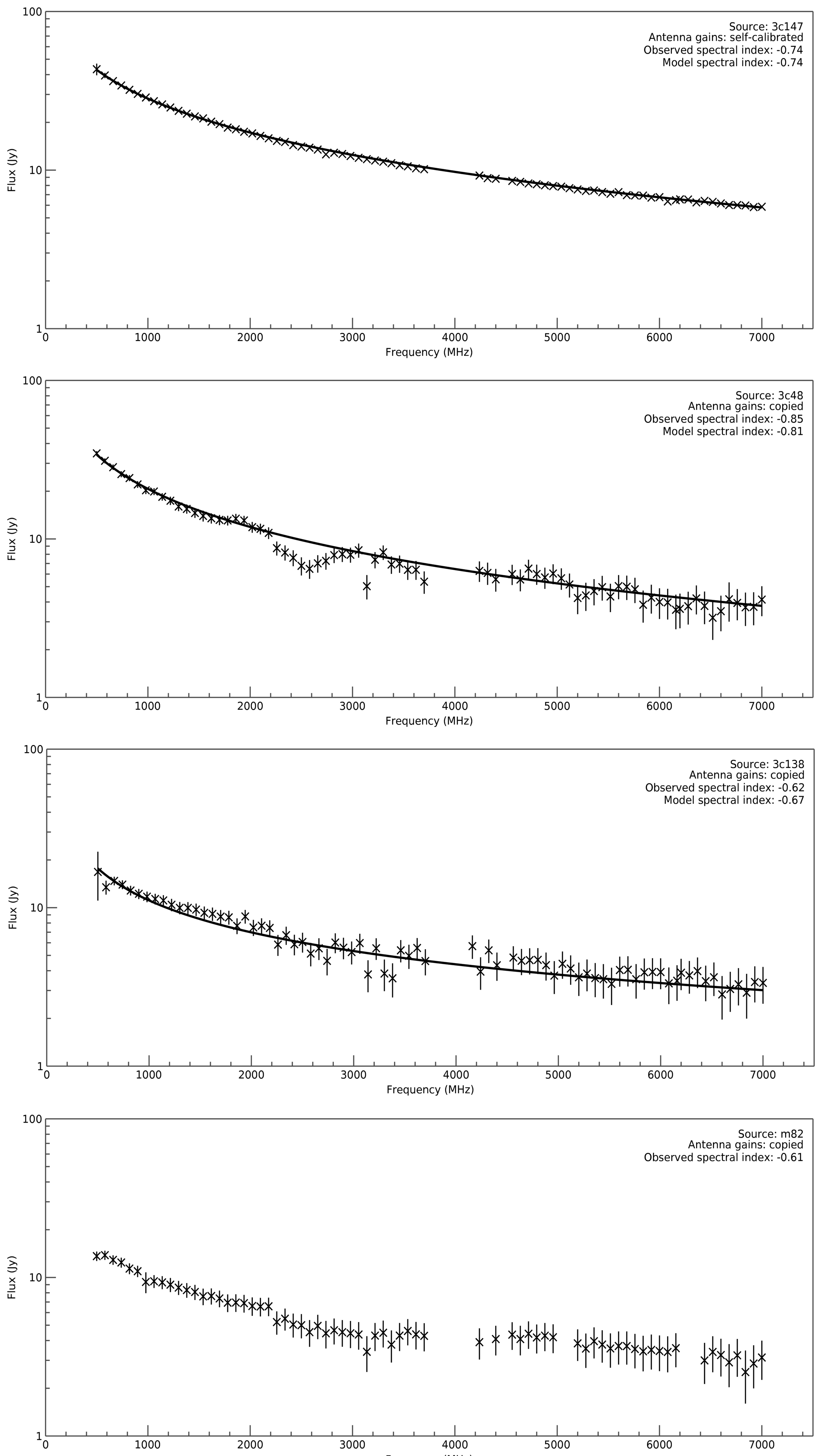
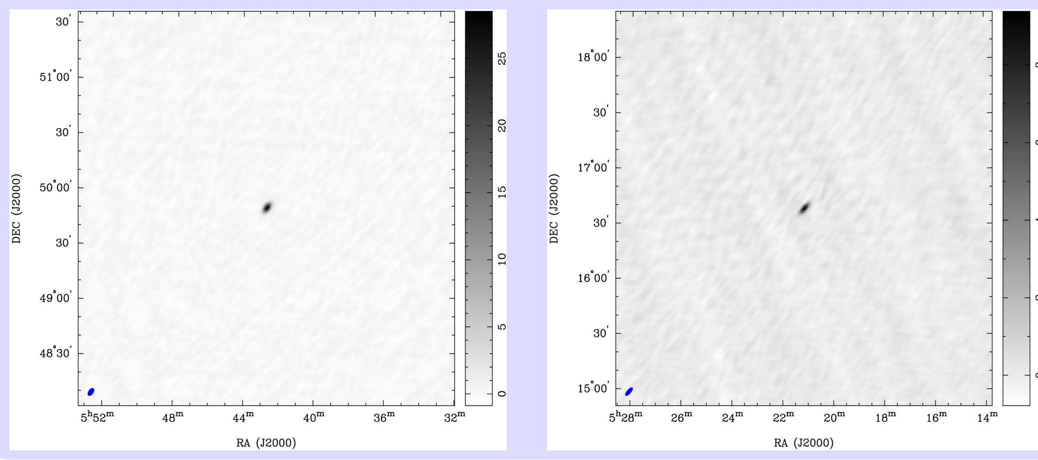
SETI INSTITUTE

ALLEN TELESCOPE ARRAY

Using 3c147 as a calibrator, we obtained broadband, high-resolution spectra of 3c48, 3c138, and M82, spanning frequencies from 0.5 to 7 GHz.





Images

The image to the far left is of the reference source, 3c147, at 980 MHz, a band with a moderate amount of RFI. The nearer image shows 3c138 at the same frequency. Because 3c138 is a fainter source and the antenna gains and data flags are optimized for the 3c147 data, the left image is perceptibly cleaner than the right, though the quality of the 3c138 image is more than sufficient to determine fluxes to good precision. Higher-SNR images can be obtained from longer integration times (both images here were generated from two minutes of integration) or via multifrequency synthesis of data in several spectral windows.

Motivations

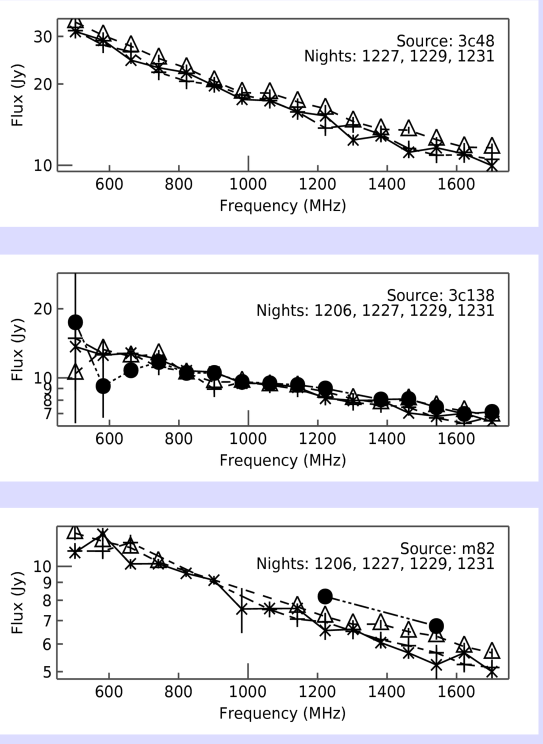
- Use the ATA to obtain continuous spectra and assess their quality with comparisons to well-known sources. Future work will obtain continuous spectra of Jupiter and other planets. Broadband spectra could also be used to probe the electron cooling times of starburst regions.
- Measure ATA antenna gains across a large range of frequency.
- Characterize the RFI environment of Hat Creek in detail to aid in the planning of future observations and surveys.

Conclusions

- The ATA can be used to obtain broadband spectra of sources even in high-RFI bands. The upper frequency limit of these observations is a function of the current state of the ATA focusing mechanism. Impending technical improvements will enable observations up to 11.2 GHz.
- Based on fits to *a priori* models, the fluxes we obtain are accurate to ~13%.
- Repeated measurements of a given source at a given frequency are consistent with one another to ~9%.

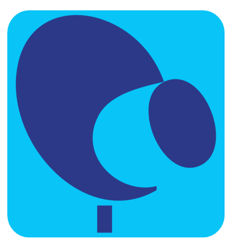
Repeatability

The targets were observed at frequencies from 0.5 to 1.7 GHz on four separate nights. At right, the spectra obtained from each individual night's observing are grouped by source and plotted. Even in this RFI-heavy region of the spectrum, repeatability is good with systematic variations and uncertainties of comparable size. The full spectra to the left combine the data from all four nights to generate results of higher precision than could be obtained individually.

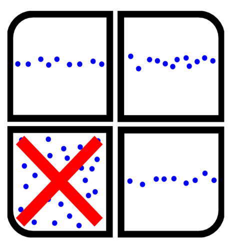


Analysis Procedure

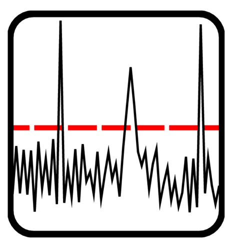
Observing. The reference source (3c147) and science targets (3c48, 3c138, and M82) are observed in a sequence of one-minute integrations at various frequencies. An observing run typically covers a range of ~1.5 GHz with individual observations spaced by 80 MHz.



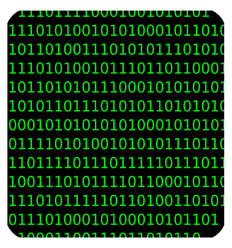
Phase closure flagging. The data are examined for phase closure errors. Those baselines frequently associated with bad closures are flagged.



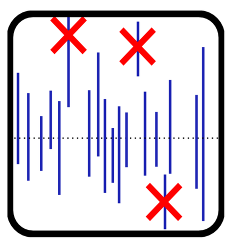
RFI flagging. High-duty-cycle RFI is flagged by examining the summation of *all* of the data in a given band. Amplitude spikes above an interactively-specified cutoff are considered RFI and flagged as bad.



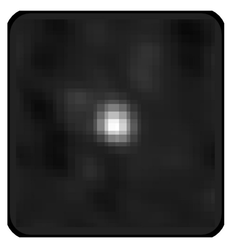
Averaging and download. The data are averaged in time to reduce their volume by a factor of ~10, then downloaded to Berkeley from the Hat Creek intranet.



Self-cal flagging. After the baselines associated with bad phases closures are flagged out, a subsample 3c147 data are interactively flagged until they yield acceptable self-calibration results. The consistently bad baselines are flagged out in all of the night's data.



Imaging and fitting. Antenna gains are determined from a self-calibration of the 3c147 data assuming the Baars *et al.* model. The gains are transferred to the rest of the data and used to make images, from which fluxes are determined with point-source models.



Empirical correction. Because the self-calibrated antenna gains are optimized for the 3c147 data, the fluxes computed for the other sources are systematically too small. Model spectra of 3c48 and 3c138 are used to compute an empirical correction factor and uncertainties.

RFI at Hat Creek

This plot characterizes the RFI environment at Hat Creek. It shows the summed signal amplitude for each spectral channel in the entire 6.5 GHz frequency range our observations covered. Even though there is a large amount of interference at 1 GHz and below, the high resolution of the ATA correlator makes it possible to obtain good results even in this noisy environment.