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Miriad for SMA Data Reduction

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Abstract. Multichannel image reconstruction, image analysis, and display (*Miriad*) is a command line based software package, originally developed to handle data from the BIMA millimeter array telescope. The software package has been adapted for the reading, calibration, and imaging of the Submillimeter Array (SMA) data. In this conference, we report and outline the data reduction procedure that has been used for processing SMA data with the *Miriad* software.

1. The Submillimter Array

The Submillimeter Array (SMA)[1] is an 8-element radio interferometer located atop Mauna Kea in Hawaii. Operating at frequencies from 180GHz to 700GHz, the 6m dishes may be arranged into configurations with baselines upto 509m, producing a synthesized beam of sub-arcsec. Each element can observe with two receivers simultaneously, with 2GHz bandwidth each. The digital correlator backend allows flexible allocation of thousands of spectral channels to each receiver.

2. Miriad for SMA Data Reduction

Miriad is a radio interferometer data reduction package (Sault, Teuben & Wright 1995) and has been adopted by the SMA for data reduction.[2] *Miriad* can be configured for the specifications required by the SMA. Specific codes for handling the SMA data have been developed and are supported. *Miriad* now can be used for the reduction of continuum and spectral line observations from loading of the SMA archival data through to the image analysis.The SMA features have particular emphasis on aspects of interest to users of the SMA. We support the off-line software including software tools used for calibration and analysis of the SMA data observed at submillimeter wavelengths. The newly developed codes are (will be) placed under *Miriad* CVS system (./miriad_cvs/src/prog/sma) which is managed by the CARMA group.

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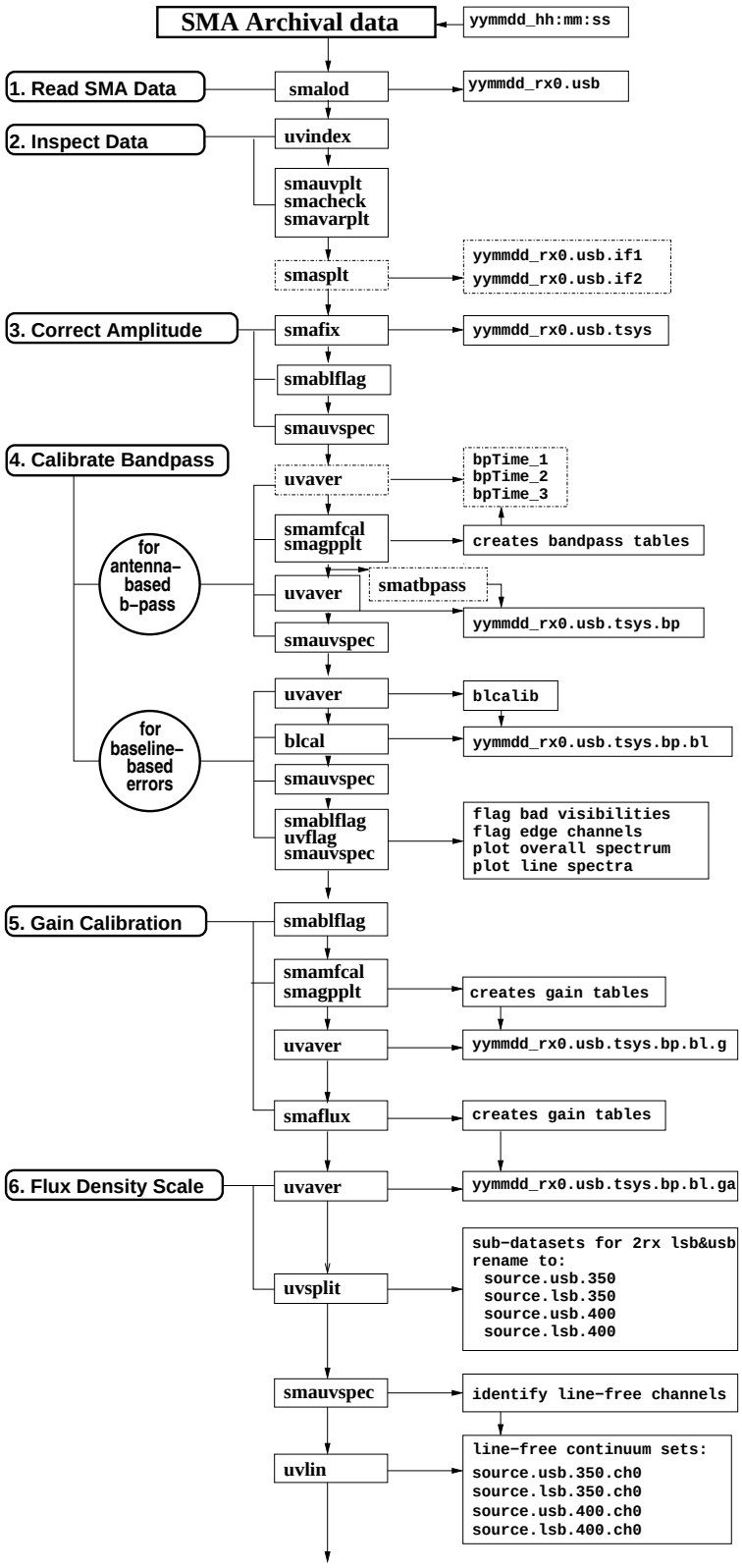
[1]The Submillimeter Array is a joint project between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics and is funded by the Smithsonian Institution and the Academia Sinica.

[2]http://www.cfa.harvard.edu/sma/miriad/


SMA Archival data
yymmdd_hh:mm:ss
1. Read SMA Data
smalod
yymmdd_rx0.usb
2. Inspect Data
uvindex
smauvplt
smacheck
smavarplt
smasplt
yymmdd_rx0.usb.if1
yymmdd_rx0.usb.if2
3. Correct Amplitude
smafix
yymmdd_rx0.usb.tsys
smablflag
smauvspec
4. Calibrate Bandpass
uvaver
bpTime_1
bpTime_2
bpTime_3
smamfcal
smagpplt
creates bandpass tables
for antenna–based b–pass
uvaver
smatbpass
yymmdd_rx0.usb.tsys.bp
smauvspec
uvaver
blcalib
for baseline–based errors
blcal
yymmdd_rx0.usb.tsys.bp.bl
smauvspec
smablflag
uvflag
smauvspec
flag bad visibilities
flag edge channels
plot overall spectrum
plot line spectra
5. Gain Calibration
smablflag
smamfcal
smagpplt
creates gain tables
uvaver
yymmdd_rx0.usb.tsys.bp.bl.g
smaflux
creates gain tables
6. Flux Density Scale
uvaver
yymmdd_rx0.usb.tsys.bp.bl.ga
uvsplit
sub–datasets for 2rx lsb&usb
rename to:
source.usb.350
source.lsb.350
source.usb.400
source.lsb.400
smauvspec
identify line–free channels
uvlin
line–free continuum sets:
source.usb.350.ch0
source.lsb.350.ch0
source.usb.400.ch0
source.lsb.400.ch0

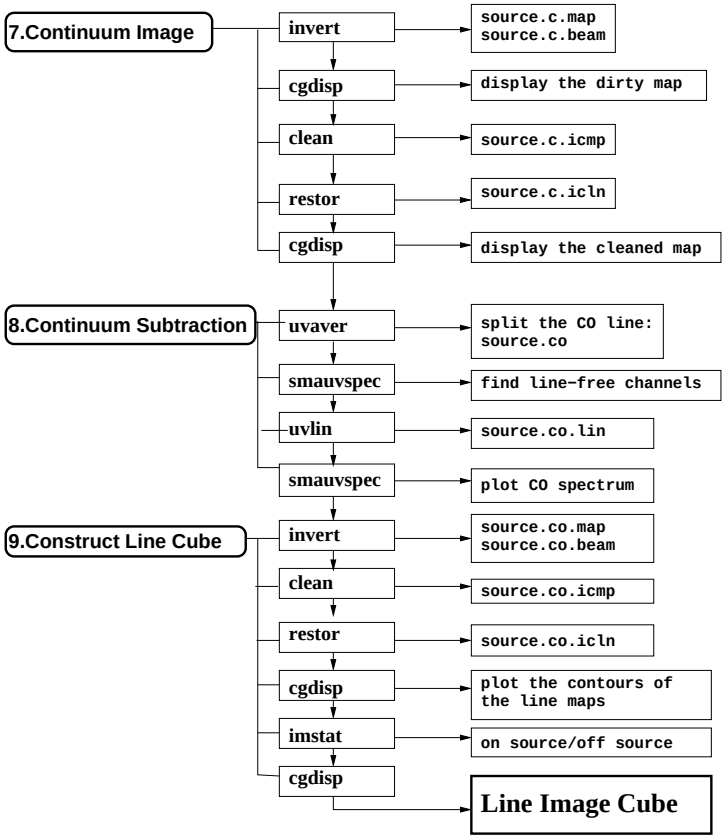


Figure 1. A flow chart of handling SMA data in *Miriad*. *Left column* shows the major steps of the data reduction procedure. *Middle column* lists the *Miriad* tasks used in the process. *Right column* shows the final calibrated uv data and image files as well as the interim uvdata, gain table and image files produced from the data reduction process.

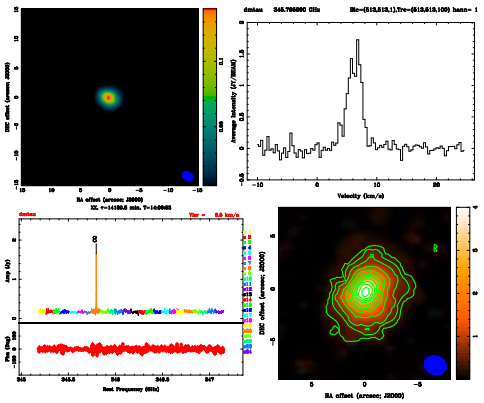


Figure 2. The result plots produced from one of the example scripts based on SMA observations of DM Tau. *Top-left*: a continuum image of DM Tau made with the data from LSB and USB of both 350 and 400 receivers. *Bottom-left*: a spectrum of USB from 350 GHz receiver. *Top-right*: a CO(3-2) line profile. *Bottom-right*: an image of integrated CO line emission from DM Tau.

2.1. Powered for Submillimeter Data Reduction

SMA planet models have been used for flux density scale calibration for the submillimeter observations in *Miriad*.[3] The SMA planet models have been coded in *smaflux*. Also, *smamfcal* is implemented with running-smooth and polynomial fitting algorithms to enhance the S/N for weak bandpass calibrators, and visibility-intensity weighting to weight down the lower S/N visibilities in the case of a resolved planet disk source to be used as bandpass calibrator. Various plotting tasks are implemented with color indices for identifying sources, spectral windows, and polarization components.

2.2. A Step-by-step for SMA Data Reduction

A step-by-step procedure for the reduction of both SMA continuum and spectral line data can be summarized by nine major steps: 1) read the archival data; 2) inspect data; 3) corrections for system temperature; 4) bandpass corrections; 5) complex gain calibration; 6) flux-density scale calibration; 7) imaging continuum emission; 8) continuum subtraction; 9) Construction of spectral line cube. Fig. 1 shows a flow chart of processing SMA data in *Miriad* from reading data, calibrations to final images.

2.3. Tutorial Scripts

One of the nice features in *Miriad* is that the detailed procedure of input setup and execution of data reduction tasks can be compiled in a shell script program. SMA staff have taken the advantage to provide users tutorial examples in C-shell scripts for reducing data acquired from the basic observing modes including hybrid-spectral resolution, dual receivers, polarization, mosaic with the standard SMA correlator configurations (2GHz bandwidth) or the double-band modes (4GHz bandwidth). The examples of the scripts have been posted on the SMA-Miriad webpage.[4] Fig. 2 shows the result plots from one of the example scripts (a non-polarization, 2 receiver mode) based on the test data from observations of DM Tau.

3. Future Plan

In the near future, the SMA backend will be implemented with a broad-band digital correlator producing tens of thousands of spectral channels to each receiver. A typical size of data produced from an observing track will exceed 50 Gbytes. *Miriad* can be adapted for the SMA upgrade.

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References

Sault, R. J., Teuben, P. J. & Wright, M. C. H, 1995, in *Astronomical Data Analysis Software and Systems IV*, ed. by R.A. Shaw, H.E. Payne, & J.J.E. Hayes, ASP Conference Series, Vol. 77, p433

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[3]Mark Gurwell, http://sma1.sma.hawaii.edu/planetvis.html

[4]http://www.cfa.harvard.edu/sma/miriad/spec/SMAscripts/