# AIPS++ Reduction and Analysis of GBT Single-Dish Spectral Data

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**Abstract.** AIPS++ is composed of a suite of tools that are capable of both astronomy-specific and general purpose calculations and data processing. Mathematical analysis, data visualization, GUI development, database handling, and scripting are all integrated. A tool for analyzing single-dish data, DISH, is developed on this platform. DISH includes a number of modern features such as bulk processing of datasets and versatile GUI interaction. Recent improvements in the command line interface ease the learning curve and provide facile interaction with scan-based data. Here we give an example of the look and feel of the current command line interface in DISH.

Although its use is not limited to one telescope, DISH includes plug-in functions that relate specifically to calibration and processing of data from the Green Bank Telescope (GBT). The GBT offers versatile spectral line observing capabilities, all of which are handled by the DISH tool. Our example illustrates a simple reduction of total-power, position-switched data showing OH maser emission from an ultraluminous infrared galaxy.

## 1. Introduction

### 1.1. The GBT

The Green Bank Telescope,[1] located at the National Radio Astronomy Observatory (NRAO) in West Virginia, is a new 100-m diameter antenna with an unblocked aperture and an active surface. It is designed to operate at sky frequencies between 300 MHz and 100 GHz. The active surface provides remarkable aperture efficiencies, e.g., 50% – 60% at 22 GHz over all elevations, a figure that will continue to improve as commissioning proceeds. Considering the state of the art receivers and backends as well, the GBT offers a number of scientifically attractive features including full sky coverage, a clean beam at all frequencies, and a significant advance in sensitivity, especially at 3 mm – 2 cm wavelengths. First light on the GBT was on August 22, 2000; the commissioning program is continuing. Meanwhile, a growing number of spectral line projects are being assigned science time.

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[1]`http://www.gb.nrao.edu/GBT/GBT.html`

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## 1.2. AIPS++

The Astronomical Information Processing System (AIPS++) is a software package designed and written by an international team of astronomers and computer scientists. AIPS++ is comprised of both general purpose and directed software tools that are tied together by a scripting language called Glish. While AIPS++ is intended to supercede classic AIPS for reduction of synthesis radio data, it also has the larger scope of addressing general data analysis problems. Both aperture synthesis and single-dish radio astronomical data are stored in a common format (the Measurement Set), making it possible to apply many common AIPS++ tools to either type of data.

The attractive general-purpose data analysis environment includes tools for line and image plotting and analysis, model fitting, GUI development, astronomical coordinate conversions, data table handling, and general scientific scripting.

AIPS++ is in the public domain. Complete documentation can be found at http://aips2.nrao.edu.

## 2. DISH

DISH is the AIPS++ tool for reducing spectral line single-dish radio astronomical data. DISH uses a feature-rich plotter and a GUI that are described in the AIPS++ documentation available from the web page. For access to data in an online environment and to facilitate scripting, a more traditional command line interface has recently been developed for DISH. The CLI borrows much of its philosophy from familiar packages such as UNIPOPS and CLASS. The concept of a *globalscan* is used in DISH to simplify syntax. Most functions operate on the *globalscan* by default, including functions such as *show, scale, bias, baseline, gauss, hanning,* etc. The *globalscan* is in fact a Glish record that contains a complete description of a raw integration or reduced spectrum, including the data itself and a full header, flags, weights, and so on.

Part of the general philosophy of AIPS++ is to give the user complete access to the data records, making it possible to examine and modify data with great versatility. Glish itself offers a full suite of programming constructs and it includes array-based mathematical operations, so it is straightforward for the user to develop his own set of functions to complement the existing ones. Incorporating the CLI-based DISH functions into user-defined functions is also trivial, so even the occasional user can develop procedures to simplify repetitive processing techniques. For example, the user might write a simple procedure to inspect all scans in the opened data set, one-by-one, like so:

```
scanlist := d.lscans()
for (i in scanlist)
 d.plotc(i)
```

DISH can be used to produce publication-quality plots. The DISH plotter is built on the widely known PGPLOT package, and the full suite of capabilities (such as notation) are easily incorporated via the plotter tool.

## 3. Sample Data Reduction Session

The following example shows a sample data reduction session in DISH, presented to give the reader a sense of the look of the CLI. A complete Users' Manual and Reference Guide are available on the web in the AIPS++ documentation sections.

```
% dish                          # From the unix prompt, this
                                #   begins an AIPS++ session
                                #   and creates the DISH tool
                                #   referred to as "d".
                                #   d.show() hence calls the
                                #   dish function "show"


- d.import('/home/gbtdata/AGBT02B_28_02','ohmaser',
            startscan=23,stopscan=28)


                                # The import function converts
                                #  GBT FITS data to DISH format
- scans := [24,26,28]           #  define a glish vector of scans
- d.calib(scans)                #  calibrate the data
- d.plotc(24)                   #  inspect the scans; suppose
- d.plotc(26)                   #    we notice RFI in channels
- d.plotc(28)                   #    440-460 in all 3 scans
- d.flag(scans,channel=440:460) #  flag the bad data
- d.accum(scans)                #  add scans to the accumulator
- d.ave()                       #  average scans in accumulator
- d.show()                      #  plot result
- d.setregion()                 #  define region for baseline
                                #    fitting using the cursor
- d.nfit(5)                     #  set polynomial order=5
- d.bshape()                    #  inspect the baseline fit
- d.baseline()                  #  subtract the baseline fit
- d.show()                      #  plot result
- d.scale([0.5,1])              #  scale the data, different for
                                #    each polarization to correct
                                #    for a Tcal scaling problem
- d.show()                      #  plot result
- d.avgFeeds()                  #  average polarizations
- d.show()                      #  plot result
- d.hanning()                   #  apply Hanning smoothing
- d.setYUnit('Jy')              #  Set units for purpose of plot
                                #   (does not change calibration)
- d.show()                      #  plot result
- d.gauss(1)                    #  fit a gaussian, result shown
                                #    below
Gauss:  1
Center: 3.58792e+04   Height: 5.41358e-02    Width: 1.25593e+02
```
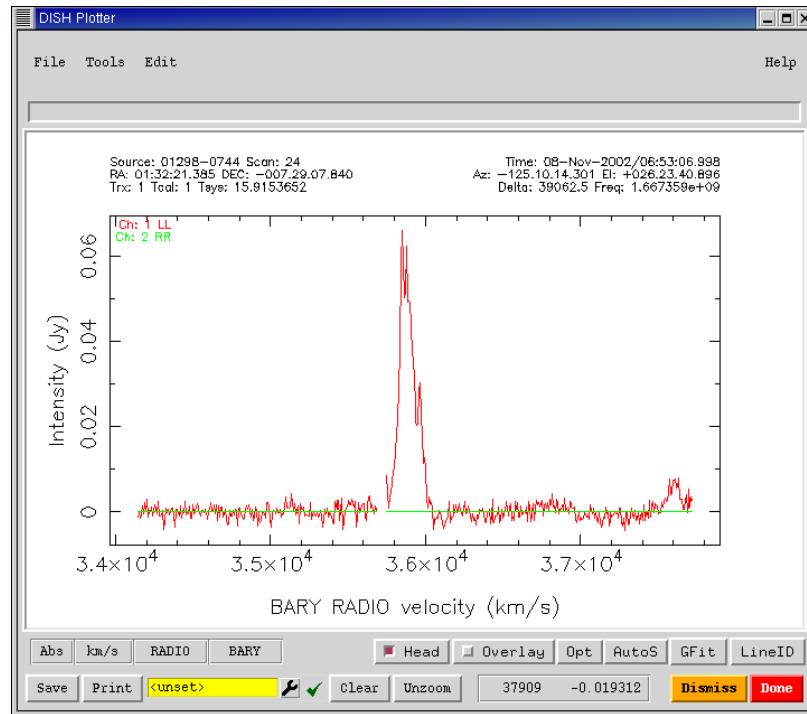
Figure 1.    The DISH plotter showing the result of the sample data reduction script. The line reveals OH maser emission.

```
Cerr: 1.05840e+00    Herr: 9.30979e-04     Werr: 2.49234e+00

- d.fileout('my_saved_data')      #  open file for saving result
- d.save()                        #  save the result
```

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