FPTOOL: A GUI for the Analysis of Fabry-Perot Data in IRAF

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Abstract. A graphical tool is being developed for the analysis of imaging Fabry-Perot data within IRAF. Constructed using the IRAF GUI interface, the tool provides the user with an integrated approach to the visualization and analysis of three-dimensional Fabry-Perot data. The tool includes both image and spectral visualization features, to provide for interpreting the cube in either of the two common ways: as a stack of images or as a grid of spectra. The use of image frame markers provides a tight interaction between the two windows.

`FPTOOL` provides a means for both visualizing and manipulating the large three-dimensional data structures produced by Fabry-Perot observations. The available analysis tools spread across the range of Fabry-Perot analysis requirements: from building cubes out of constituent unevenly sampled images, to cube arithmetic, to line profile fitting, sky subtraction, and velocity map creation. While the necessary automation exists for rapid spectral reduction of Fabry-Perot data, features such as spatial masking allow for more detailed analyses as well.

`FPTOOL` demonstrates the power of the IRAF GUI interface and is an important step in an integrated approach to the Fabry-Perot data analysis problem.

1. Fabry-Perot Data Analysis

Historically, the analysis of imaging Fabry-Perot data has been a daunting task, requiring complex software techniques (Bland & Tully 1989) and expensive hardware capable of rapidly processing and storing the large data sets. The latter of these restrictions has been lifted in recent years with the advent of powerful workstations and large, fast disk storage at prices cheap enough to make them accessible to the average scientist. However, the analysis of large and complex Fabry-Perot data sets still proves a formidable obstacle to the astronomer due to the lack of standard reduction packages. Most Fabry-Perot astronomers use small non-portable software distributions which have been developed in-house, usually tailored to a specific instrument or observing style.

Motivated by the lack of a standard toolset for the analysis of Fabry-Perot data, we are currently developing a Fabry-Perot package in IRAF (Bland-Hawthorn, Shopbell, & Cecil 1992). Written in native SPP code, this package is the first attempt to provide the astronomical community with an organized system for reducing Fabry-Perot data, within the common image processing environment of IRAF.

The IRAF Fabry-Perot package has now been greatly enhanced through the use of one of the most important recent developments in the IRAF environment: GUIs. While graphical user interfaces (GUIs) have been commonplace since the introduction of the Macintosh personal computer, IRAF has been slow to adopt graphical front-ends for their packages, primarily due to questions of portability and longevity. The IRAF GUI system, which is being distributed as a part of IRAF 2.11 (and as an add-on package to IRAF 2.10), provides a method of isolating hardware- and graphics display-dependent code from the user-level graphics interface. This allows a developer to add a GUI to a task by composing a single command script which is passed to a "widget server" at runtime. This script is interpreted by the server and instantiated on the selected graphics device. At this time the server supports X Window System graphics output.

The IRAF GUI system provides a number of standard widgets, including scroll bars, radio buttons, labels, frames, and lists. In addition, a widget that has been customized for astronomical applications is included: the XGterm widget. The XGterm widget has support for the display of both line and image graphics and has been used to develop the `xgterm` and `ximtool` clients, X11 tools which replace their obsolete Sunview counterparts. `FPTOOL` is the first attempt to take advantage of these new IRAF graphics capabilities in order to support the analysis of Fabry-Perot data.

2. Visualization of Fabry-Perot Data with FPTOOL

`FPTOOL` is a software tool, written in IRAF/SPP, for interactive graphical reduction and analysis of imaging Fabry-Perot interferometer data. Fabry-Perot data typically consists of three-dimensional data cubes, where the axes are both spatial (X, Y) and spectral (Z). This multi-dimensionality has two primary implications: First, visualization of the data set becomes an extremely complex problem. Radio astronomy is one of the few subfields where we have seen extensive use of 3D visualization techniques for astronomical applications. Tools such as `AIPSView` (Crutcher 1996), can be useful to Fabry-Perot astronomers in this regard. Second, Fabry-Perot data analysis techniques contain features common to both two-dimensional imagery and slit spectroscopy. Thus few tools from either of these fields can be readily adapted to Fabry-Perot studies without modification. `FPTOOL` has been developed with both of these issues in mind.

Three-dimensional Fabry-Perot data visualization is a complex problem which may be solved as advanced 3D graphics systems become more commonly available over the next few years. `FPTOOL` approaches this issue by providing interdependent visualization of both the spatial and spectral domains of the data. (See Shopbell & Bland-Hawthorn 1995; Figure 1.) As shown in Figure 1, the two primary windows provided by `FPTOOL` are an image display window and a spectral grid display window. This approach is simpler to develop and elimi-

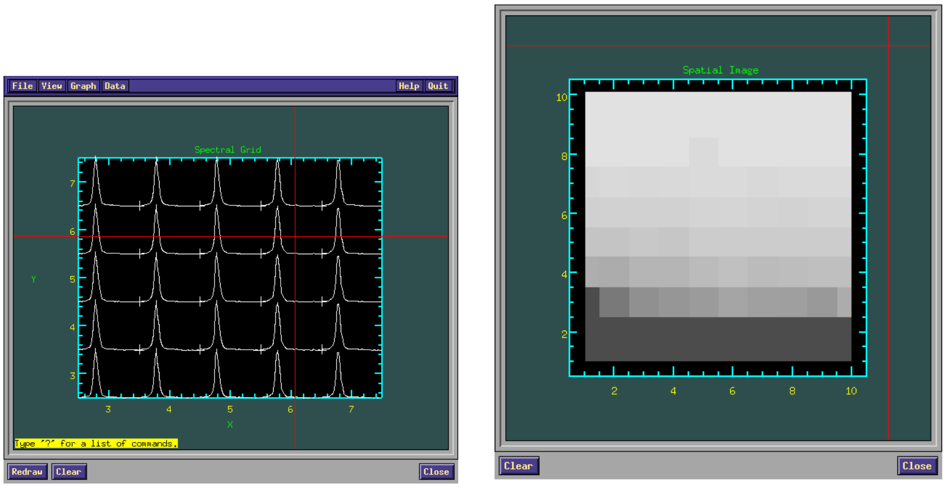

Figure 1. Prototypes of the primary FPTOOL windows: a spectral grid display and an image display.

nates the steep learning curves of many 3D visualization tools, since each of the windows are familiar to the observational data analyst.

The image display window resembles an `ximtool` window, although the controls have been developed specifically for Fabry-Perot imagery. The primary control is a scroll bar which allows the user to select a frame along the spectral (Z) dimension for display. Multiple frames may be selected and the binned result displayed as well, in order to examine the flux from an entire line profile, for example. The scroll bar can be scanned to demonstrate trends in the line profiles over both spatial and spectral domains. Since it is intended for use in data analysis and not final presentation, the image display window does not provide the degree of detail and customization (e.g., colormap selection) that is found in the `ximtool` client.

The spectral display window resembles other tools used in slit spectra analysis, such as IRAF's SPLOT. The most significant enhancement in FPTOOL has been the addition of support for two-dimensional grids of spectra. Just as with the image display window, scroll bars are provided for scanning along the spatial (X, Y) axes of the data cube. The window into the spectral domain may thereby be moved throughout the spatial field of view. The grid may be zoomed, stretched, and binned as well.

Finally, the image and spectral display windows are interactively linked: a box ("marker" in IRAF GUI terms) is maintained in the image display window to indicate the spatial extent of the spectra displayed in the spectral window. This box is not merely illustrative, however, and may be moved and resized to select a desired field of spectra for display.

3. Analysis of Fabry-Perot Data with FPTOOL

Perhaps the most important aspect of FPTOOL is the integration of both image and spectral data reduction tools into a single task that has been optimized for Fabry-Perot data analysis. For example, support is provided for cosmic ray removal as well as spectral line identification. Other Fabry-Perot analysis features include frame sorting and interpolation, spectral extractions based on complex masks, and slit simulations. However, it should be noted that `FPTOOL` is merely a portion of the IRAF Fabry-Perot package and is not intended as a single tool for end-to-end Fabry-Perot data reduction. More complex reductions, such as frame alignment, Fabry-Perot phase correction (Shopbell, Bland-Hawthorn, & Cecil 1992), and ring fitting (Shopbell, Bland-Hawthorn, & Cecil 1993) are best accomplished using the dedicated IRAF tasks developed specifically for those problems.

While there are a number of simple utilities that have been included in `FPTOOL` for convenience, such as cube arithmetic and spatial filtering, the spectral analysis portions of `FPTOOL` have been developed primarily to solve the Fabry-Perot analysis problem of spectral fitting. In most cases, the number of spectra of interest in a data cube far exceeds the manual capabilities of even the most dedicated researcher. Some form of automation is clearly required to fit several hundred thousand spectra. `FPTOOL` has integrated the single spectrum fitting algorithms of the `ONEDSPEC` package with a set of inheritance-based automatic fitting procedures. The user need merely fit a few select spectra which are representative; `FPTOOL` will fit the rest. For compatibility and ease of use, the manual fitting interface closely matches that used by `SPLOT`. Multiple components and lines may be fit using Gaussians, Lorentzians, and Voigt profiles. Spectra may be masked, weighted, and smoothed. Additional details of the underlying spectral fitting capabilities can be found in Shopbell & Bland-Hawthorn 1995.

`FPTOOL` provides an integrated, graphical, IRAF-based approach to the complex data analysis problems associated with imaging Fabry-Perot data. The power of the IRAF GUI system has been used to create a visualization tool to assist in the quantification and understanding of large Fabry-Perot data sets. As such, `FPTOOL` is an important component of the IRAF Fabry-Perot package.

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