

STSDAS: THE SPACE TELESCOPE SCIENCE DATA ANALYSIS SYSTEM

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INTRODUCTION

STSDAS is a system of some 750,000 lines of code and documentation designed for the calibration and analysis of data from the Hubble Space Telescope. At its inception in 1981, when it was known simply as 'SDAS', the system was dependent on the VAX VMS operating system and architecture and was limited in scope to HST data analysis, excluding calibration. As it was realized that astronomers would want to be able to do their own calibrations of HST data, and that it was not cost-effective, either for end-users or for the software development effort, to have a system dependent on a proprietary operating system, the scope and objectives of the system were modified. The most fundamental change was the decision to fully layer the STSDAS software on the Image Reduction and Analysis Facility – IRAF – from the National Optical Astronomy Observatories. For a review of the historical aspects of the development of STSDAS, please see Hanisch (1989).

The system now includes the capability of performing all HST data calibration using 'pipeline' type processing: all calibration options are controlled by the values of keywords in the input data file, and the software operates with essentially no user intervention. This allows the identical code to be run from within the on-line Post Observation Data Processing System (PODPS) for HST (see the paper on HST in this volume) as is used in the off-line STSDAS software. Users are free to tailor the off-line calibration and inspect intermediate data products that are not typically made available in the on-line system. STSDAS also includes a suite of calibration support software. These programs are used to analyze HST calibration data and generate the appropriate sensitivity parameters, flat fields, wavelength scales, etc., that are utilized in the pipeline calibration processing. The calibration software is organized into separate IRAF packages, one for each major scientific instrument. STSDAS also provides access to the HST Calibration Data Base via simple database queries.

STSDAS includes a number of applications packages of a more generic nature, although some of these have features that are tailored to HST data. For example, there are packages for Fourier analysis, isophote fitting, and synthetic photometry, to name a few, but at this time the synthetic photometry package only has HST filters available. In order to cope with the spherical aberration problem on HST, a new set of image restoration algorithms is being provided. Several of the most basic techniques – Fourier inverse, Wiener filter, and Lucy-Richardson algorithm – have already been implemented.

Other packages in STSDAS complement the general graphics, image display, and data manipulation packages in IRAF. For example, the STSDAS task *igi* (for interactive graphics interpreter) allows for the production of publication quality graphics using a command interpreter syntactically similar to MONGO. Other ST-specific graphics capabilities include the ability to make finder charts and overlays from the ST Guide Star Catalog, and to superimpose the HST field of view diagram on an image. STSDAS provides its own FITS

I/O package in order to accommodate the idiosyncracies of the STSDAS disk data format, and to provide support for I/O of tabular data.

SYSTEM CAPABILITIES

Calibration and Synthetic Photometry

The calibration software for each scientific instrument on HST is grouped together in an STSDAS package: *wfpc*, *foc*, *hrs*, *fos*, *hsp*, and *fgs*. The primary task in each package is the corresponding pipeline calibration program *calxxx* ('xxx' is the instrument name, thus, *calfoc*, *calwfp*, etc.). Other tasks in these packages support the analysis of calibration data, and are used primarily by the instrument scientists at ST ScI.

A major feature of the STSDAS *wfpc* package is a modified version of the IRAF *imcombine* task. The WF/PC data is severely affected by cosmic rays, and given the sharp core of the point-spread function it can be difficult to distinguish a cosmic ray hit from a faint star. Users are advised to split their WF/PC exposures into two or more separate frames, and anti-coincidence testing can then be used to discriminate between stars and cosmic rays. The *combine* task implements this cosmic ray rejection algorithm.

An important adjunct to the instrument-specific calibration packages is the synthetic photometry package *synphot*. The *synphot* package allows users to compute the expected throughput for any HST instrument and filter combination using model spectra or observed spectra as input. The output can be given in a number of various units, and the standard astronomical filter passbands (like Johnson *UVBRI*) are supported. The package is being used in support of the absolute photometric calibration of HST.

The *synphot* package could easily be generalized to support throughput calculations for other observatories, given the appropriate filter transmission curves, allowed filter combinations, and telescope characteristics.

Analysis

STSDAS users can run all of the applications packages provided with the standard IRAF system on HST data and IRAF users can run STSDAS applications on NOAO data by virtue of the common image I/O interface. Thus, the NOAO IRAF project and ST ScI STSDAS project coordinate their applications software development.

The primary packages available for general data analysis within STSDAS are the *isophote* package for isophote fitting and surface photometry, the *fourier* package for Fourier analysis (one- and two-dimensional transforms, cross- and auto-correlation, and power spectra), and a *statistics* package containing an implementation of the non-parametric survival analysis programs developed by E. Feigelson and T. Isobe (Feigelson and Nelson, 1985, Isobe et al., 1986). We have just recently implemented several standard image restoration algorithms, and these have no particular dependencies on HST data. A general purpose curve- and surface-fitting package is available (*fitting*), and a general time series analysis package is supported.

Other Facilities

STSDAS supports a number of other analysis and data manipulation utilities, foremost of which is the STSDAS table system. STSDAS tables are binary data structures which provide

for the simple manipulation of tabular information. Columns in tables are accessed by name, so that it is easy to transfer data from one program to another using a tables interface. A large variety of tools are provided for working with tables, from an interactive editor to statistics routines to database-like interfaces. Tables are used as the output format from a number of STSDAS programs, and using the table T_EX/L^AT_EX filtering task these tables can be incorporated into T_EX files very easily. Because of the general utility of the table system, it is available separately from the rest of STSDAS as a stand-alone *tables* package.

Another package that is useful not only to HST observers is the *gasp* package. This package, which is named after the Guide Star Astrometric Support Package developed at ST ScI, provides access to the Guide Star Catalog on CDROM. Users can overlay guide star positions on HST images, or on other image files if the coordinate system is at least approximately known. A plate solution task allows one to recompute the coordinate transformation parameters for an image in accordance with the Guide Star Catalog reference frame.

DOCUMENTATION

The STSDAS system has two major user's guides: the *STSDAS User's Guide* and the *STSDAS Calibration User's Guide*. The former provides an overview of the system capabilities and gives an introduction to use of the IRAF command language. The *Calibration User's Guide* gives more detailed information on the procedures and ancillary files needed to properly calibrate HST data sets. Both a *Site Manager's Guide* and an *Installation Guide* are provided for remote STSDAS user sites.

For programmers we provide reference manuals for the F77VOS interface and for the table I/O subsystem. Users who need to understand the details of STSDAS data file formats, and the instrument-specific header information, may use *Interface Control Document 19: PODPS to SDAS*, which is maintained and provided by the STSDAS group.

SUMMARY

The STSDAS system, in conjunction with NOAO's IRAF system, provides the fundamental calibration and analysis needs for observers using the Hubble Space Telescope. The system continues to evolve and expand to meet the needs of HST GOs and ARs, with a current emphasis on image restoration software to deal with the HST spherical aberration problem. Additional software will be written to support the second generation scientific instruments (WF/PC II, the Near Infrared Camera, and the Space Telescope Imaging Spectrograph).

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