

**Data reduction and analysis facilities
for UK astronomers**

Starlink was set up to help astronomers analyse their data. It is:

- * A network of **computers** used by UK astronomers.
- * A collection of **software** to reduce and analyse astronomical data and to do some types of theoretical work.
- * A team of **people** giving hardware, software and administrative support.

Starlink's main objectives are to:

- * Provide and coordinate interactive **data reduction and analysis** facilities for use as a research tool by UK astronomers.
- * Encourage **software sharing** to prevent unnecessary duplication of effort.
- * Provide **software support** and **systems management** for astronomers.

Starlink facilities are located at about two dozen University sites around the U.K.

Starlink is run on behalf of the *Particle Physics and Astronomy Research Council* (PPARC) by the *Starlink Project Group* within the *Space Science Department* of *Rutherford Appleton Laboratory* (RAL).

RAL is part of the *Council for the Central Laboratory of the Research Councils* (CCLRC).

PPARC is one of the Research Councils funded by the *Office of Science and Technology* (OST) within the *Department of Trade and Industry* (DTI).

The astronomical images on the front and back cover were provided by the Royal Observatory Edinburgh & Anglo Australian Telescope Board and are reproduced with their permission. The front cover shows the Vela supernova remnant. The back cover shows the Trifid Nebula.

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Starlink's Software Environment

What is it?

Starlink's *software environment* (also called ADAM) supports telescope control, instrument control, data acquisition and astronomical data reduction.

To the *programmer*, it is a set of powerful subroutine libraries covering everything from positional astronomy to inter-task message passing and high level graphics.

To the *astronomer*, it is a wide range of data reduction applications and a variety of user interfaces to both data collection and data reduction.

How can I get a copy?

ADAM and data-analysis packages are distributed free by the Starlink Project to astronomical researchers. See the box at bottom left for contact information

Origins

The first ADAM system was written at the Royal Greenwich Observatory to control instruments on the 2.5 metre Isaac Newton Telescope, and ran on 16-bit Perkin-Elmer mini-computers.

The system was then ported to VAX/VMS by the Royal Observatory Edinburgh, and enlarged to incorporate much of the prototype data analysis environment under development by the Starlink Project at the Rutherford Appleton Laboratory.

In 1990, an ADAM support group was formed at RAL, and the parts of the system used in data reduction were ported to a variety of UNIX systems. Work to port the remaining components is in progress at RAL and the Royal Observatories.

Why is it called ADAM? The original Perkin-Elmer system was called the Astronomical Data Acquisition Monitor (ADAM). However, this no longer adequately describes the ADAM system as it exists today. Over the years several other names have been suggested, but none has stuck.

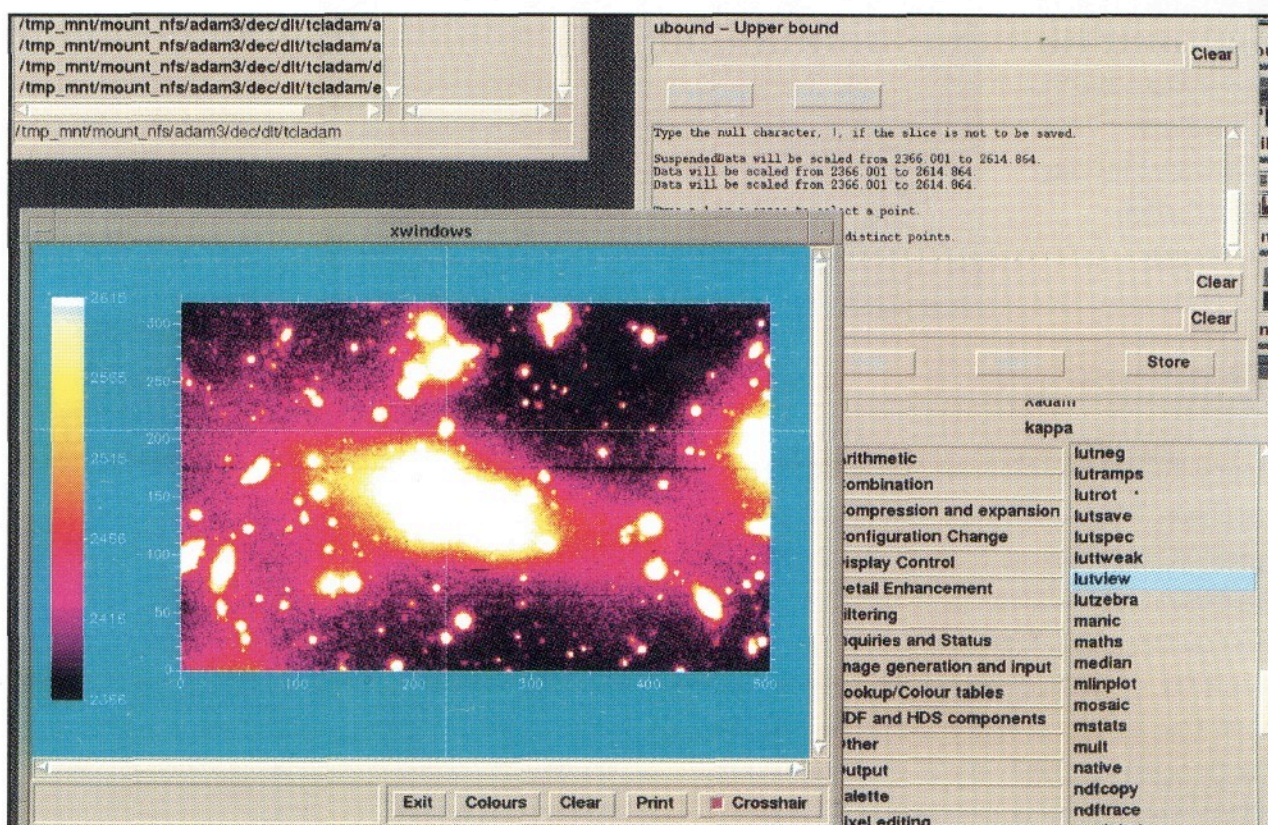
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What is it used for? Who uses it?

On-line control:

ADAM controls the JCMT millimetre telescope and the UKIRT infrared telescope on Hawaii. ADAM also controls data acquisition and instrumentation at these sites, and at the UK's other overseas telescope sites in Australia and the Canary Islands.

Data reduction and analysis:

ADAM provides the software environment which supports data analysis applications used by UK astronomers. It is also used by astronomers for writing their own software.

What does it run on?

Data analysis:

SUN Sparc
(SunOS or Solaris)
DEC AXP
(OSF/1)
DEC MIPS
(Ultronix)
Intel PC - under development
(Linux)

Telescope & Instrument control:

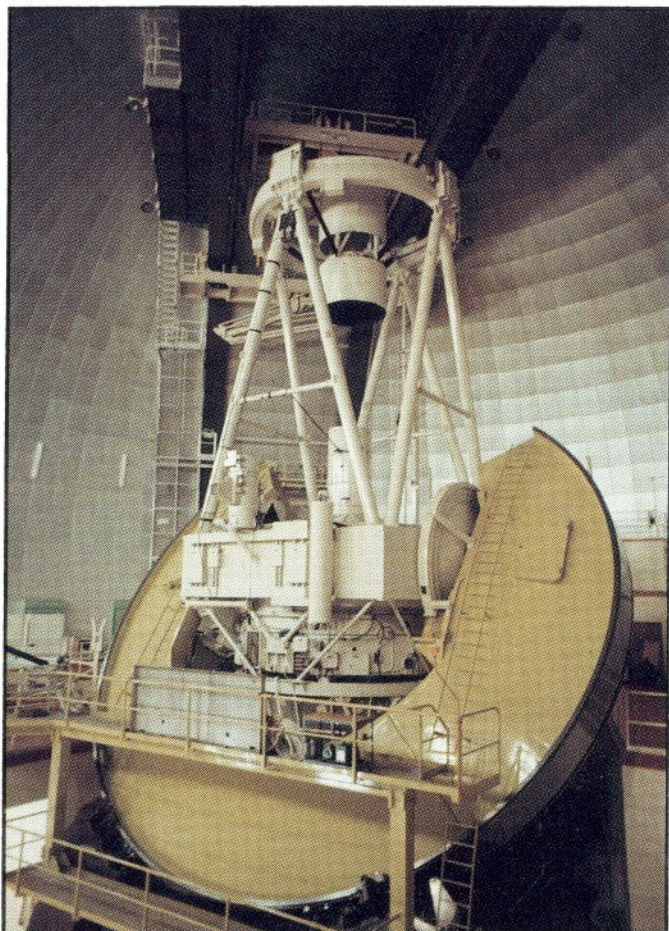
VAX/VMS
OSF/1 & Solaris - soon.

Components

The ADAM software is divided into several major components:

1) User interfaces:

ADAM tasks can be controlled by a variety of user interfaces; for example, the Interactive Control Language (ICL) provides a traditional line-oriented command interface. Graphical user interfaces can be written using a version of the Tk toolkit which has been extended to use the ADAM message system.



2) Parameter system:

Every ADAM task has a set of "parameters." Each parameter has a name and a value that can be read by the task. The value can be set by the user supplying it when the task is invoked, or in response to a prompt from the task. It may also be set by the program itself, by a static configuration file, or by a message from another task (typically a user interface).

If there isn't a user interface task, the parameter system will prompt using the standard input and output; so an ADAM task can be run directly from a terminal like a normal program, if necessary.

Subroutine Libraries

- Graphics
- Positional astronomy
- Data storage
- Character handling
- Message & Error reporting
- Interactive help
- Magnetic tape handling
- Inter-task notice board
- Parameter system
- Catalogue access
- Image display

3) Data storage system:

Storage of data on disk is handled by the Hierarchical Data System (HDS), which is optimised for storing large (>1 Mbyte) data arrays with associated ancillary information (e.g. exposure times, sky coordinates etc.). Every data item in an HDS file has a name and is organised in a tree structure. An HDS file is "self describing" in that the name and data type of every item are stored in the file, along with the actual data. Files can be copied between machines with different data representations, the necessary conversion

being done automatically "on the fly" at the time the data set is accessed.

Standard names are used for common data elements such as the main data array, data variance array, axis information etc. The N-Dimensional Data Format (NDF) access library provides easy access to these data elements, and deals with the complexities of, for example, the presence or absence of a "data quality" array. Packages can store in their own private extensions specialised information not covered by the standard structures.

The international standard FITS format on both tape and disk can be used for data interchange.

Data Reduction & Analysis Applications

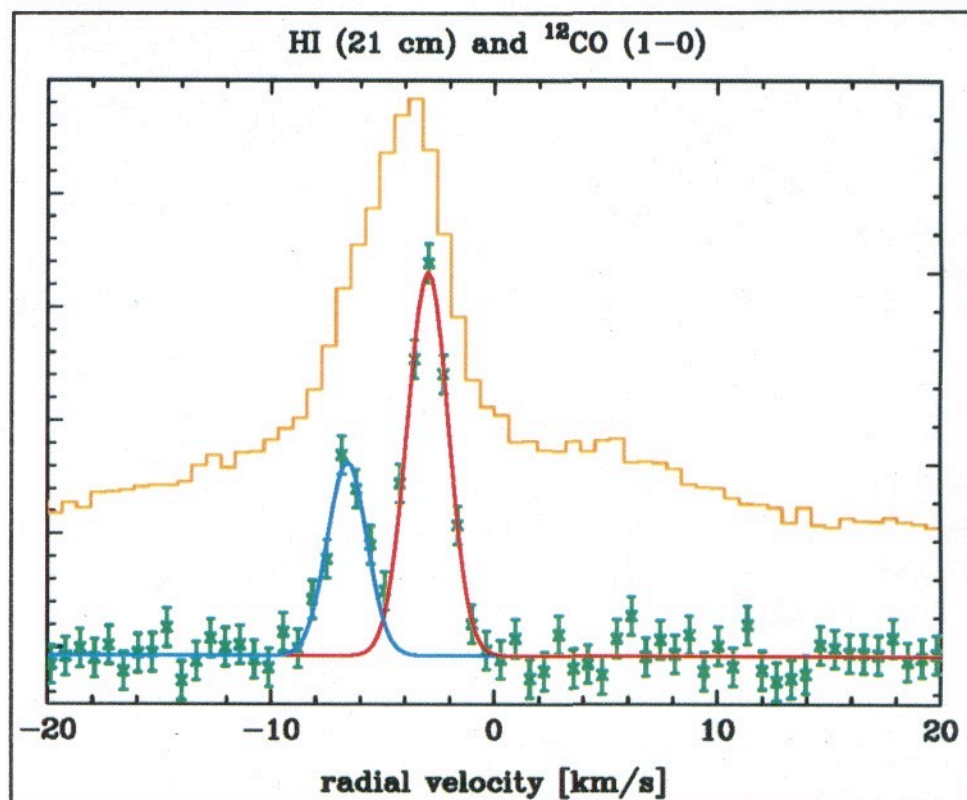
- Image manipulation & processing
- General data reduction & spectroscopy
- Automated CCD reduction
- IUE data reduction
- Stellar photometry
- Aperture photometry
- Position, intensity and shape analysis
- Spectrum analysis
- IRAS data reduction
- X-ray data processing
- Echelle data reduction
- Spectroscopy
- Galaxy photometry
- Infra-red camera data reduction

4) Graphics:

Several graphics packages are provided with ADAM, giving the applications programmer a range of flexibility and ease of use to choose from. A wide selection of graphics devices are supported, the most important at present being X for interactive graphics and PostScript for hard copy.

5) Inter-task message system:

The message system is used by ADAM tasks (UNIX or VMS processes) to communicate with other ADAM



tasks running on the same or other machines; for example, an instrument control task can send commands to the telescope control task or receive information about the telescope position. Data reduction tasks use the message system to communicate with the user interface.



Starlink Software Collection

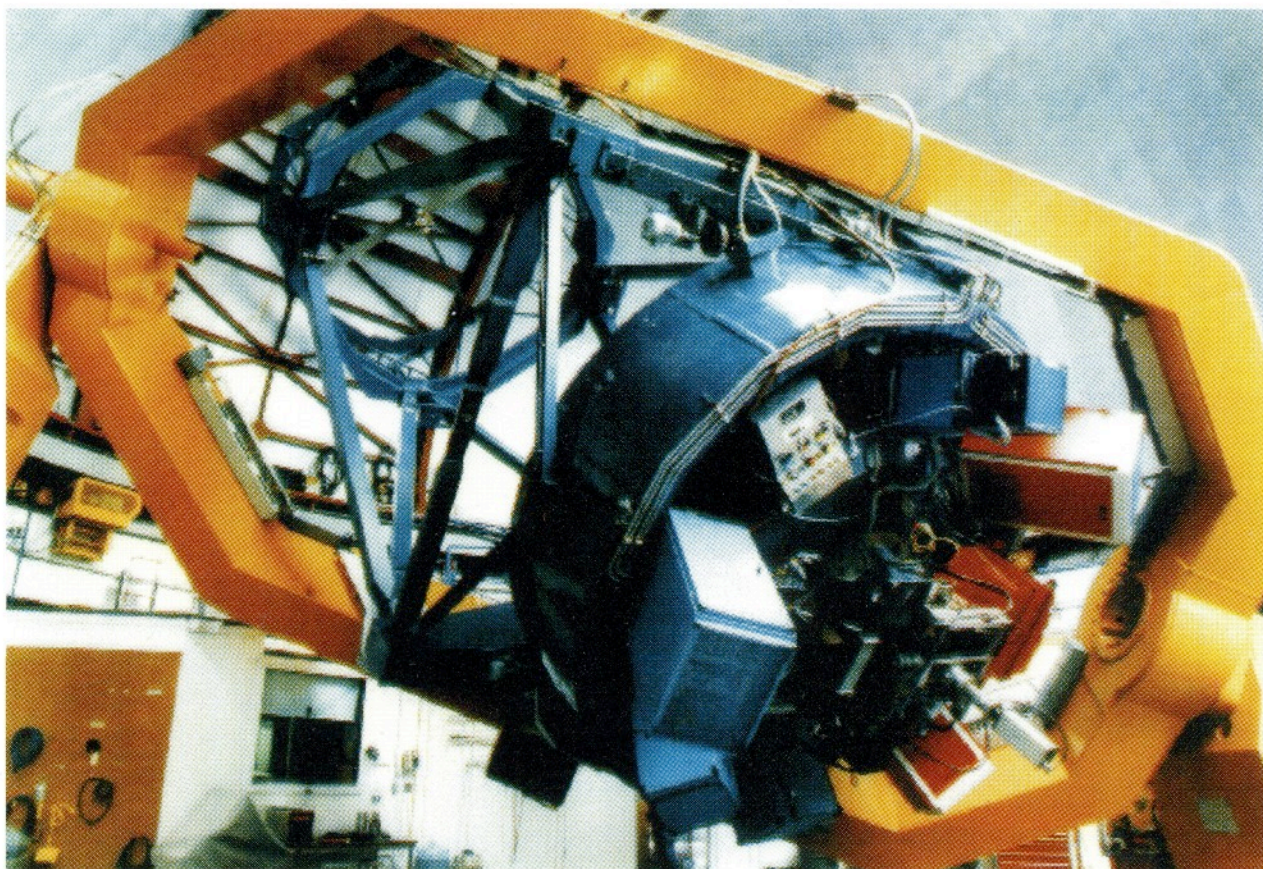
CGS4DR

What Is It?

It's a software package for reducing and analysing data from the near infra-red spectrometer on UKIRT.

UKIRT is the 3.8m United Kingdom Infra-Red Telescope in Hawaii, shown in the picture on the right. The CGS4 spectrometer is the red dewar and cabinets at the base of the mirror cell.

A command line interface is available under SunOS, Open-VMS, Solaris and Digital Unix, based on Starlink's *ICL* interpreter. A graphical user interface is available under Solaris and Digital Unix, based on *Tcl/tk*. A port to Linux is expected soon.



Courtesy ROE Photolabs

Help

CGS4DR is described in *SUN/27*, available on paper or WWW at:

<http://star-www.rl.ac.uk/docs/sun27.htm/sun27.html>

There is also a *User Support Group* that can be contacted at:

ukirt_sw@jach.hawaii.edu or http://www.jach.hawaii.edu/ukirt_sw/

The author *Phil Daly*, of the UKIRT Software Group, is available at:

pnd@jach.hawaii.edu

Why Is it Automated?

The 1 to 5 micron region of the spectrum is a rich source of atomic and molecular lines of interest to astronomers. However, the non-thermal region is also a source of strong and interfering emission due mainly to H_2O and OH^- sky lines. The thermal region is dominated by continuum emission from the sky and "warm" telescope and rises inexorably with wavelength. This is illustrated in the figure below.

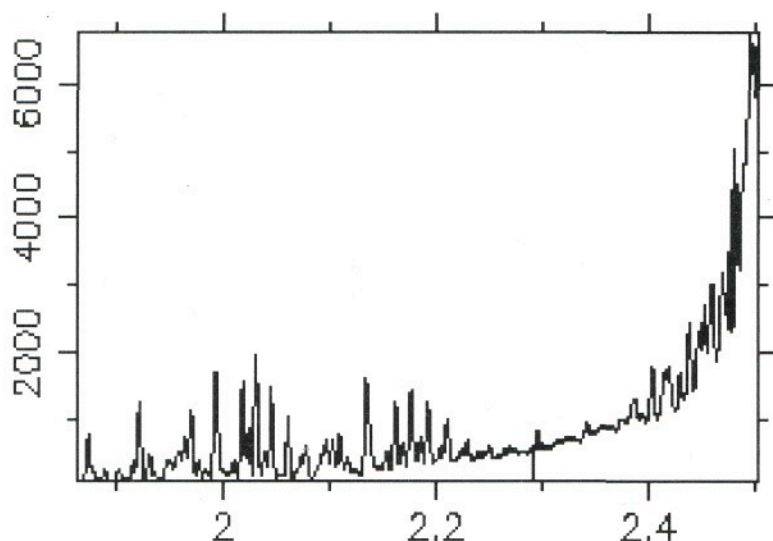
These backgrounds vary on short timescales and are several orders of magnitude brighter than astronomical sources. Thus, exposure times are short with frequent nods/chops to blank sky. Typically, this happens once per minute. During this time, CGS4 can return over-sampled data at up to 100kb every 5 seconds. If the reduction system were not automated, observers would spend most of their time typing in reduction commands to cope with the flow of data!

How Does it Work?

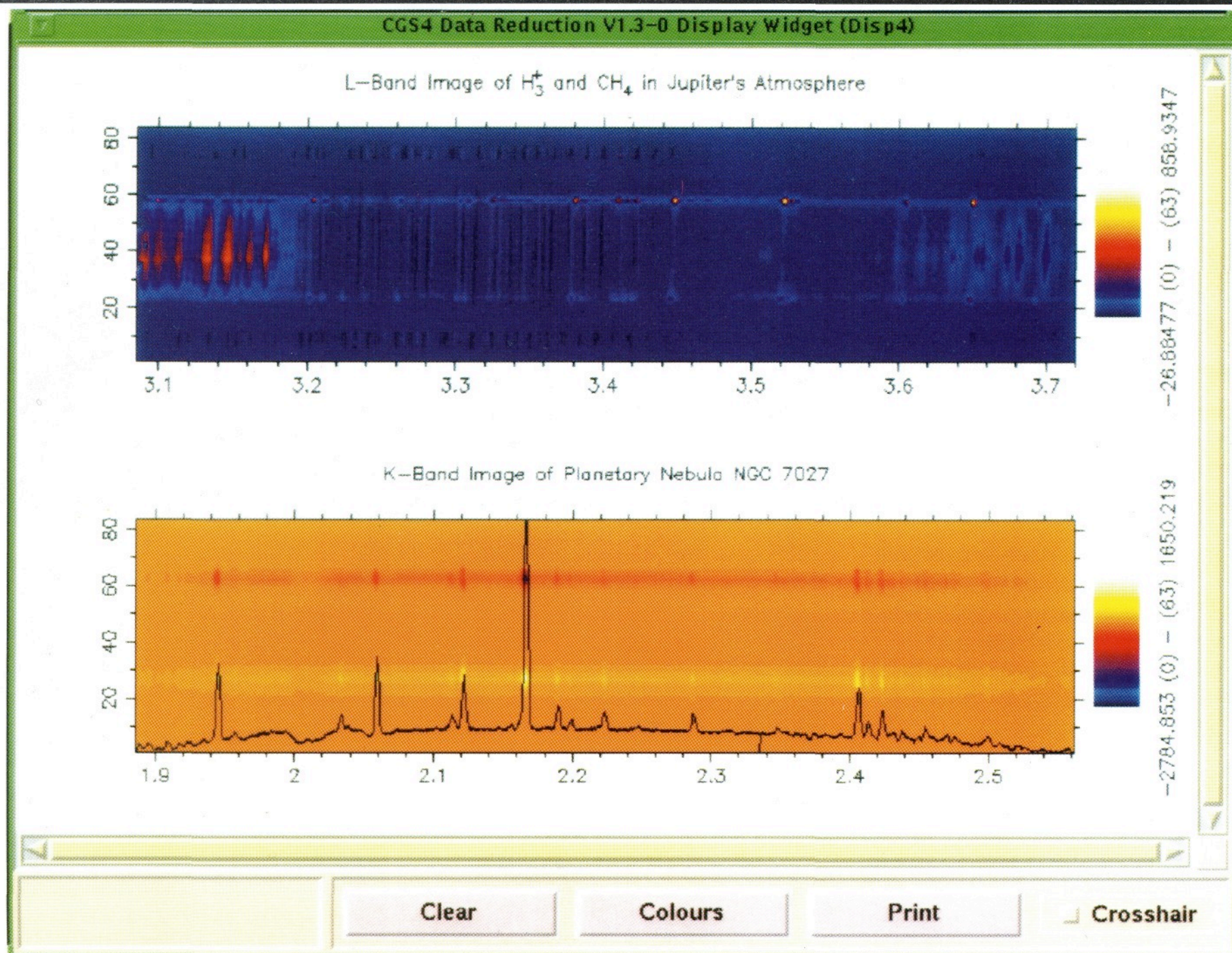
At UKIRT, the (VMS) data acquisition system sends reduction commands to the (Unix) data reduction system's queue manager using distributed ADAMnet communications. At a Starlink site, a user enters commands into the data reduction queue manually. It is this time-stamped queue that is at the heart of the automated data reduction paradigm: the controlling task reads the newest command from the queue every two seconds. Such commands are interpreted by the software and reduce the data according to the pre-defined setup.

The data reduction system recognises observations of type *bias*, *dark*, *flat*, *arc*, *object*, *sky*, *calib* and *standard*,

Infrared Sky/Telescope Emission



The K-Band Infra-Red Sky above Mauna Kea – Shortward of 2.3 μm the background includes emission from water vapour and hydroxyl radicals. Longward of 2.3 μm the background is dominated by continuum emission



Some results from CGS4DR.

[upper] L-band spectrum of Jupiter (courtesy Tom Geballe); [lower] K-band spectrum of NGC7027 (courtesy Mike McCartney).

Data Reduction Operations (CGS4DR)	Auto	Used
Apply bad pixel mask	Yes	Always
Subtract <i>bias</i> frame for STARE observations	Yes	Always
Linearise the signal	Yes	Never
Subtract <i>dark</i> frame	Yes	Sometimes
Normalise <i>flat</i> field	Yes	Always
Divide by <i>flat</i> field frame	Yes	Usually
Interlace oversampled data	Yes	Always
Apply internal wavelength calibration scale	Yes	Always
Apply external wavelength calibration scale	No	Sometimes
Coadd observations into <i>object-sky</i> pairs	Yes	Usually
Remove residual atmospheric lines	Yes	Sometimes
Divide by a <i>standard</i> source	Yes	Sometimes
Extract multiple spectra noddled along slit	Yes	Sometimes
Deripple extracted spectrum	No	Sometimes
Flux calibrate extracted spectrum	No	Sometimes
Generic graphics manipulation	Yes	Always
Manipulation of data reduction queue	Yes	Always
Flag some data as bad	No	Sometimes
Remove bad data by interpolation	No	Sometimes
Arithmetic and statistical operations	No	Sometimes
Creation of bad pixel masks	No	Sometimes
Decurve reduced spectra	Soon?	Unknown
Auto-reduce spectropolarimetric data groups	Soon?	Unknown
Auto-deripple extracted spectrum	Soon?	Unknown

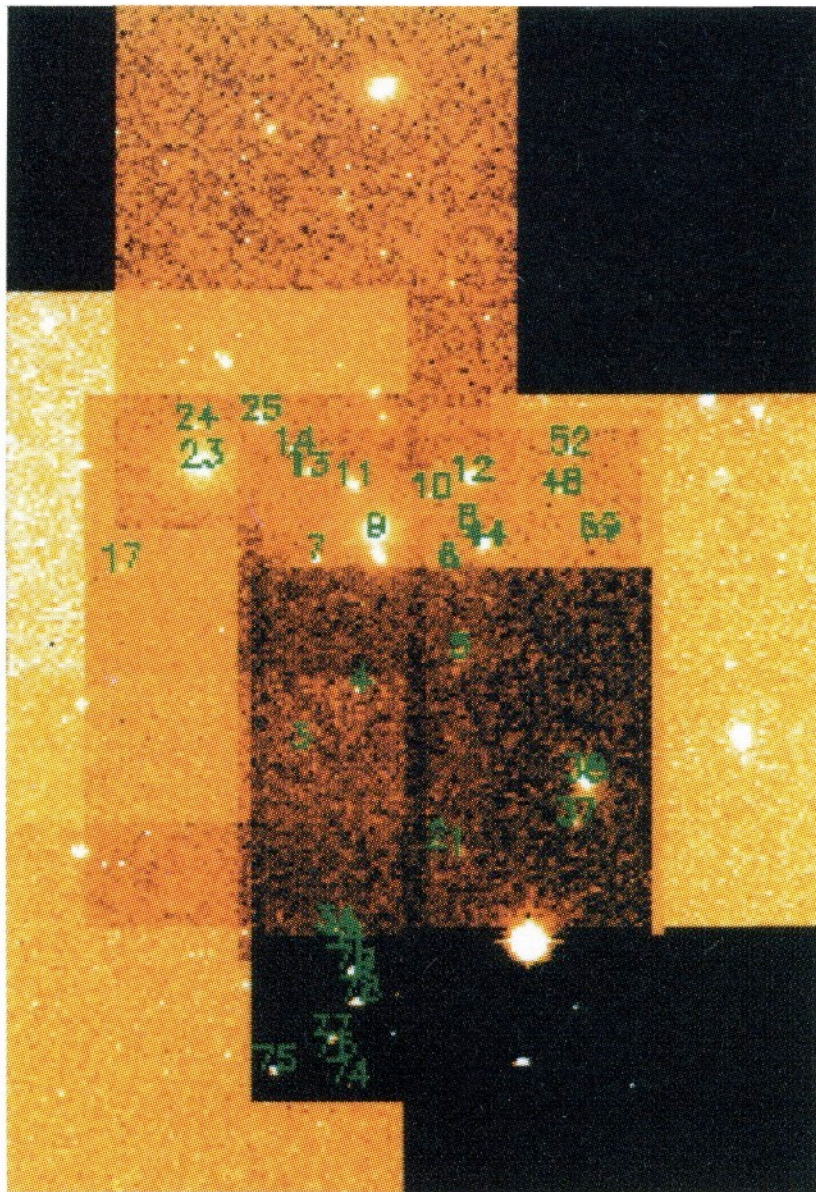
and reduces and re-uses them appropriately at the different reduction stages. The astronomer retains considerable flexibility, however, in specifying how the data are finally reduced. Available operations are listed in the table on the left.

What Can I Expect?

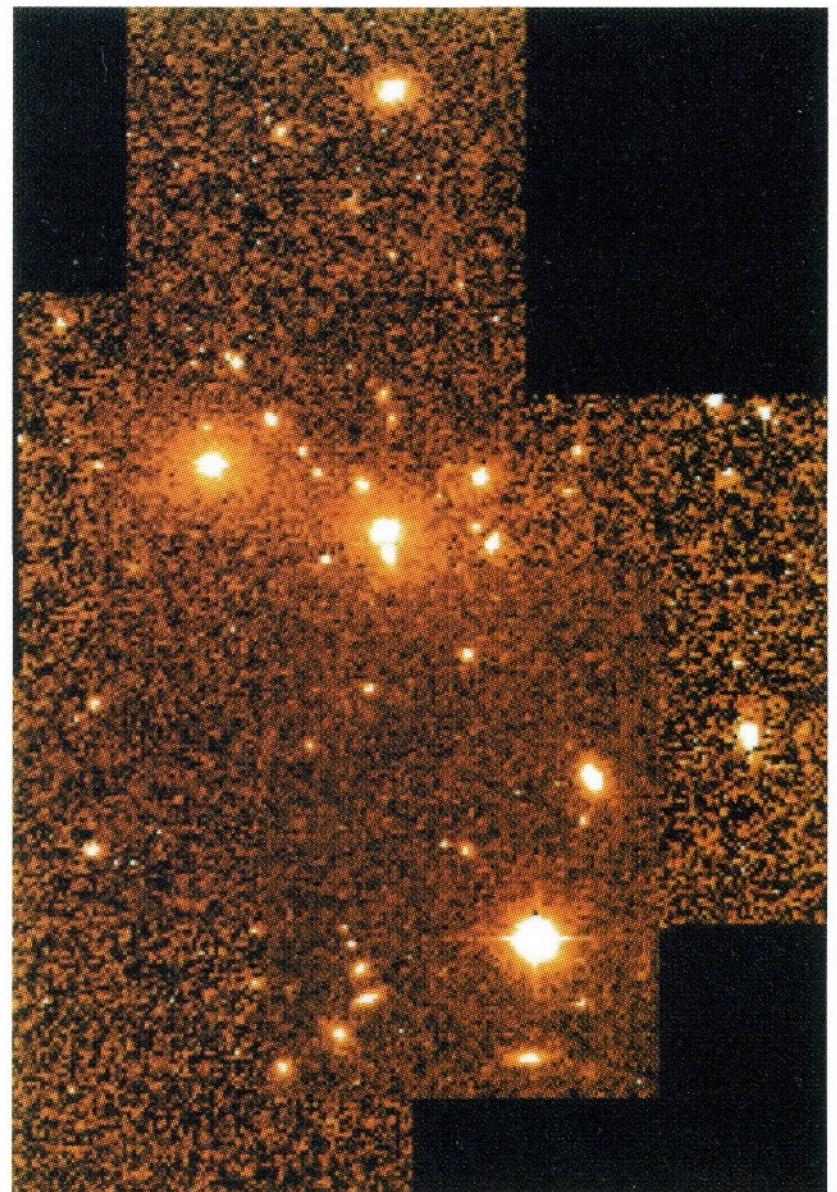
The figure above illustrates some typical results obtained by CGS4DR.

The upper image shows the detection of the exotic disequilibrium molecule H_3^+ in the Jovian atmosphere. The emission is strongest at the poles but is visible at all latitudes. At the edges of this image are a multitude of absorption lines from CH_4 .

The lower image is the result of the reduction of 78 *object-sky* pairs of the small, young planetary nebula NGC 7027 – the brightest at infra-red wavelengths. Overlaid on the image is a spectrum extracted from row 28 plotted with error bars.



This picture shows the result of automatically aligning eight overlapping images of the sky. The marked stars have been detected and identified automatically using pattern recognition. The images have then been aligned and combined into a single mosaic. The mosaic is not "flat" because of exposure and sky brightness variations.



The same images as on the left, except that they have now been "normalized." This corrects for any changes in exposure and sky brightness. Any visible variations are now due to noise changes because of the different number and quality of images present at each point.

CCDPACK is a package for reducing images taken by CCD-like detectors.

Graphical Interface

The graphical interface controls automated CCDPACK reductions. It is designed to help those with little, or no, knowledge of the package or of CCD reduction to start working effectively as quickly as possible.

It concentrates on organising and categorising your data, rather than on how and when to run individual programs. The required processing steps are deduced and then executed automatically.

Command Interface

The command-line interface offers a complete set of tools to perform the following operations on CCD data:

1. Bias estimation and removal.
2. Dark count and pre-flash correction.
3. Flatfield calibration and correction.
4. Image registration.
5. Image resampling.
6. Mosaic generation (see above).

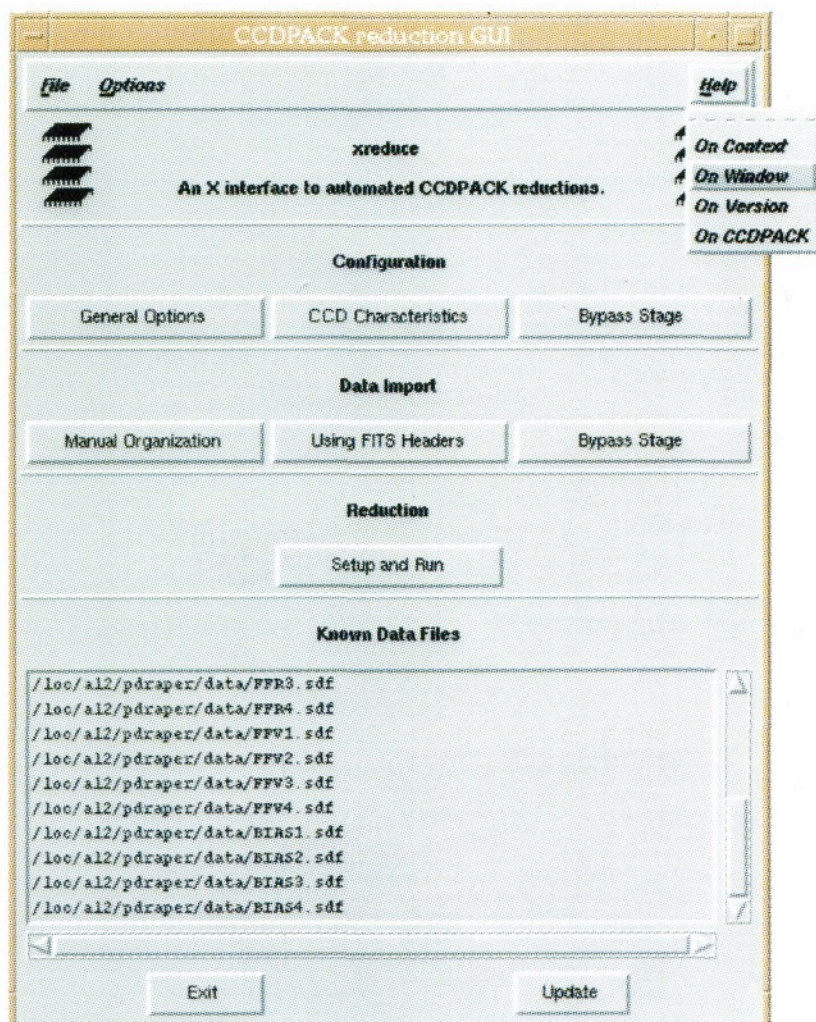
You can automate stages 1, 2 and 3.

CCDPACK can easily process large quantities of data by operating on lists

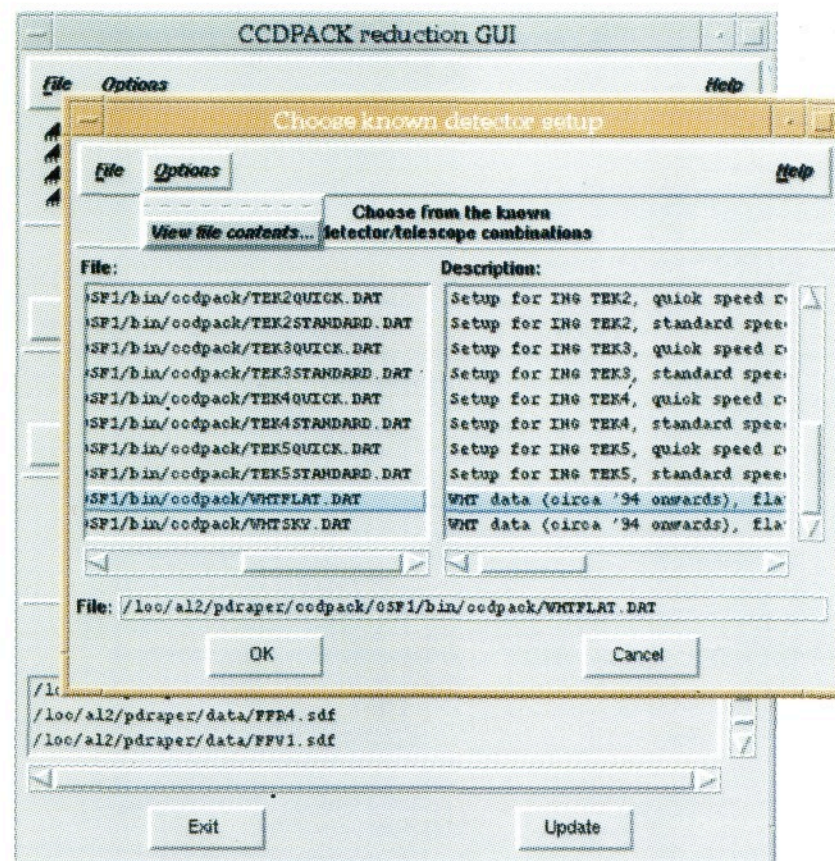
of images. All its activities can be recorded using a built-in logging system. It can also:

- * Store image defect descriptions concisely using text files.
- * Generate & propagate statistical error information.
- * Use many different image combination methods (mean, median etc.).

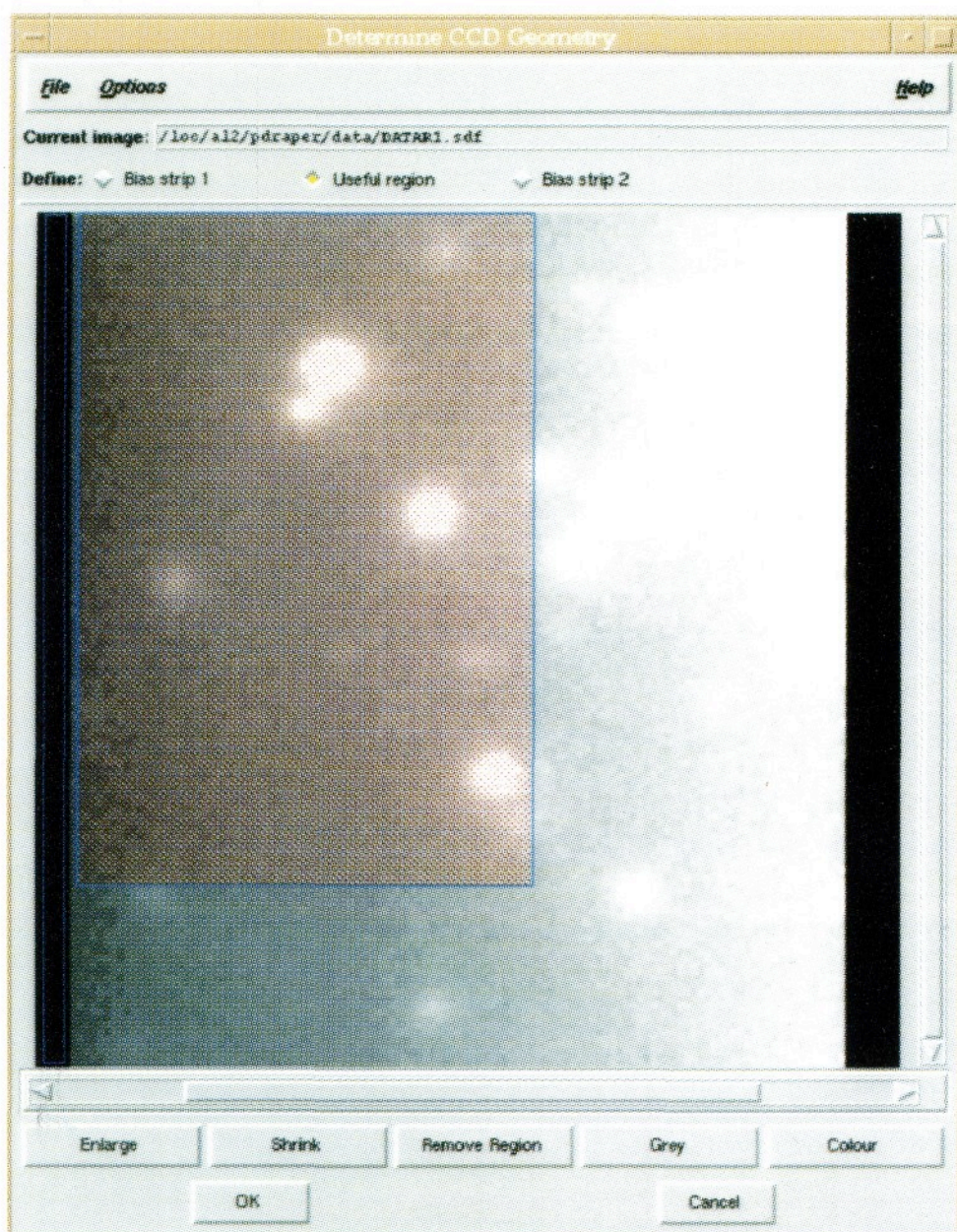
Multiple images with different scale factors and orientations can be registered. If the images have the same scale and orientation, this can be done either automatically or graphically with very little effort.



The main window of the CCDPACK graphical interface. The "Help" menu has been pulled down to reveal its commands. "On Context" tells you how to get help on any part of the window. "On Window" describes the window in overview. "On CCDPACK" gives you access to the CCDPACK user's guide.



Another snapshot of the CCDPACK graphical interface in action. This window allows you to select a known CCD camera. (If the images were taken on the WHT after 1994 they can be reduced automatically.) All that is then necessary is to identify the data files. This is done in a separate window.



If the CCD used isn't already known to CCDPACK, then it is necessary to supply some information about it. The most important parameters are the extents of the light-sensitive area and the bias strips. In this window, the image can be panned and zoomed and any of the required regions identified by dragging the mouse over them.

Help

CCDPACK is described in *SUN/139*, available on paper or WWW at:

<http://star-www.rl.ac.uk/docs/sun139.htx/sun139.html>

Paper versions can be obtained from any Starlink Site Manager.

CCDPACK is supported by Peter Draper, who is available at:

P.W.Draper@durham.ac.uk



PISA stands for *Position, Intensity and Shape Analysis*. It is a package for detecting and measuring objects in astronomical images automatically.

Locating objects

PISA's main program, PISAFIND, *locates* all the objects in an image by detecting groups of pixels that:

- * Are joined together.
- * Form a region greater than a given size.
- * Have intensities significantly greater than the background.

These criteria make the likelihood of false detections negligible.

PISAFIND calculates a set of *parameters* that describe the position, intensity and shape of each of these groups – the “objects.” Overlapping objects can also be separated from each other and estimates made of their individual parameters.

Classifying objects

PISA also *classifies* objects into different astronomical types. It uses a “peakedness” estimate (that indicates how much an object resembles a

star), together with other parameters that are, in principle, intensity independent.

This is why the objects detected by PISAFIND are coloured differently in Figure 1 – cuts in peakedness and ellipticity have been used to separate out stellar objects (green) from non-

stellar objects (yellow).

Applications

Automatic detection, deblending and parameterisation of objects in images (such as CCD frames and scanned photographic plates) is particularly useful when the number of objects involved becomes large and the task of locating and measuring each by hand isn't practicable.

Automatic measurement is particularly valuable for doing things like:

- * Counting faint galaxies and stars.
- * Studying the distribution of galaxies.

However, it can also be used in any study that needs to obtain the colour and magnitude of many objects.

Origin

PISAFIND is based on the APM IMAGES program created by Mike Irwin of the University of Cambridge.

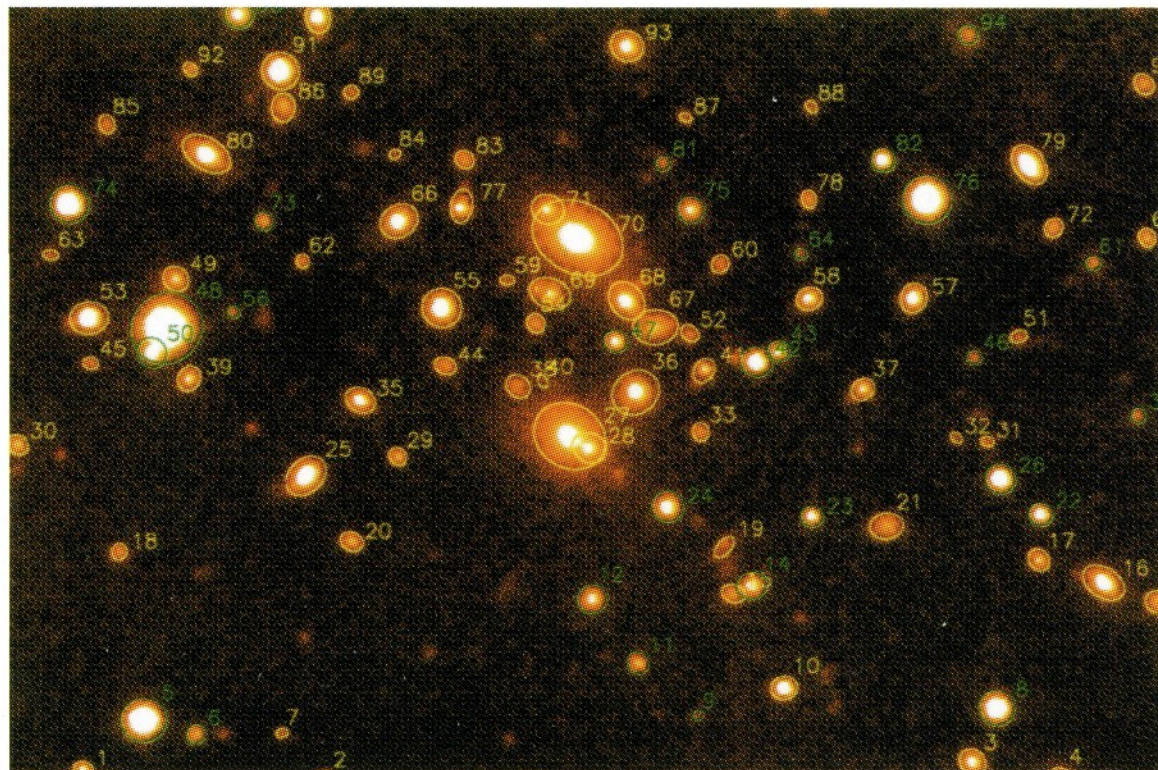


Figure 1. The results of running PISAFIND, with the detected objects overlaid on the original image. Notice how merged objects have been separated.

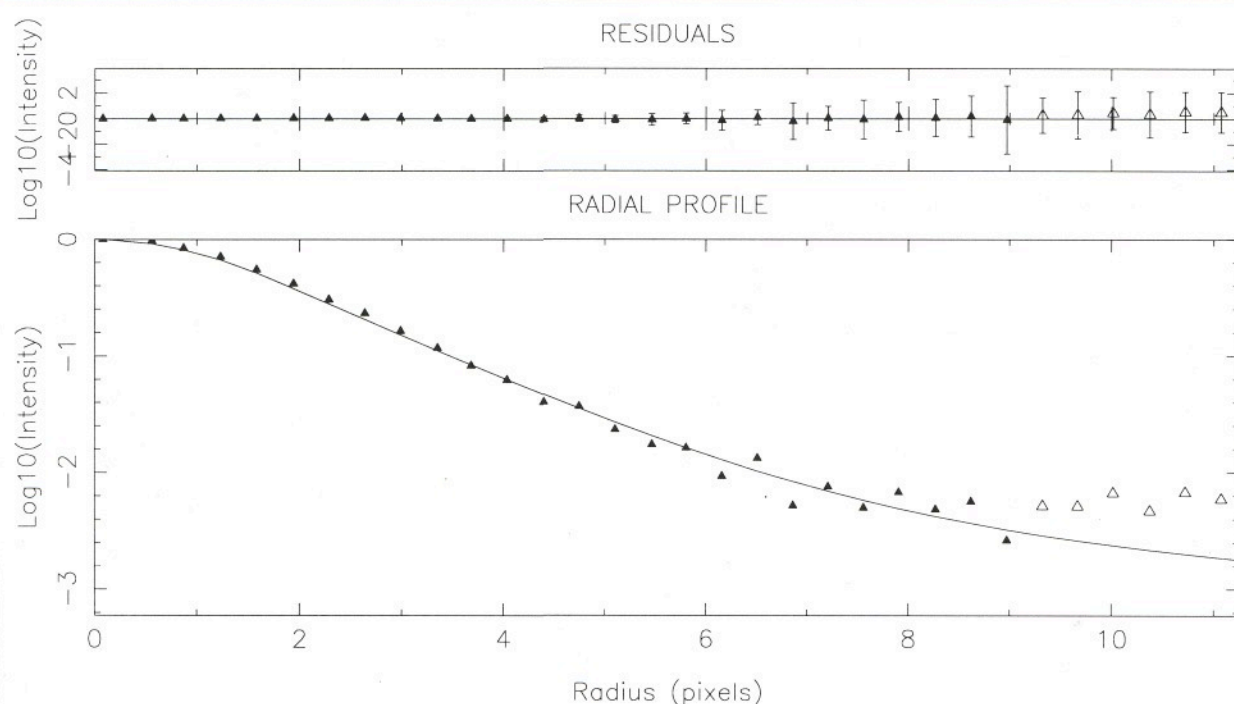


Figure 2. In addition to the object detection mode shown in Figure 1, PISAFIND can also use an algebraic model to fit stars. Before this can be done, certain characteristics of the stars must be determined. This figure shows a fit of an analytic profile to a selection of good stars in the image. Using a model fit is particularly useful when measuring low-intensity stars as some of the information necessary for a good fit (like their shape) is then known in advance.

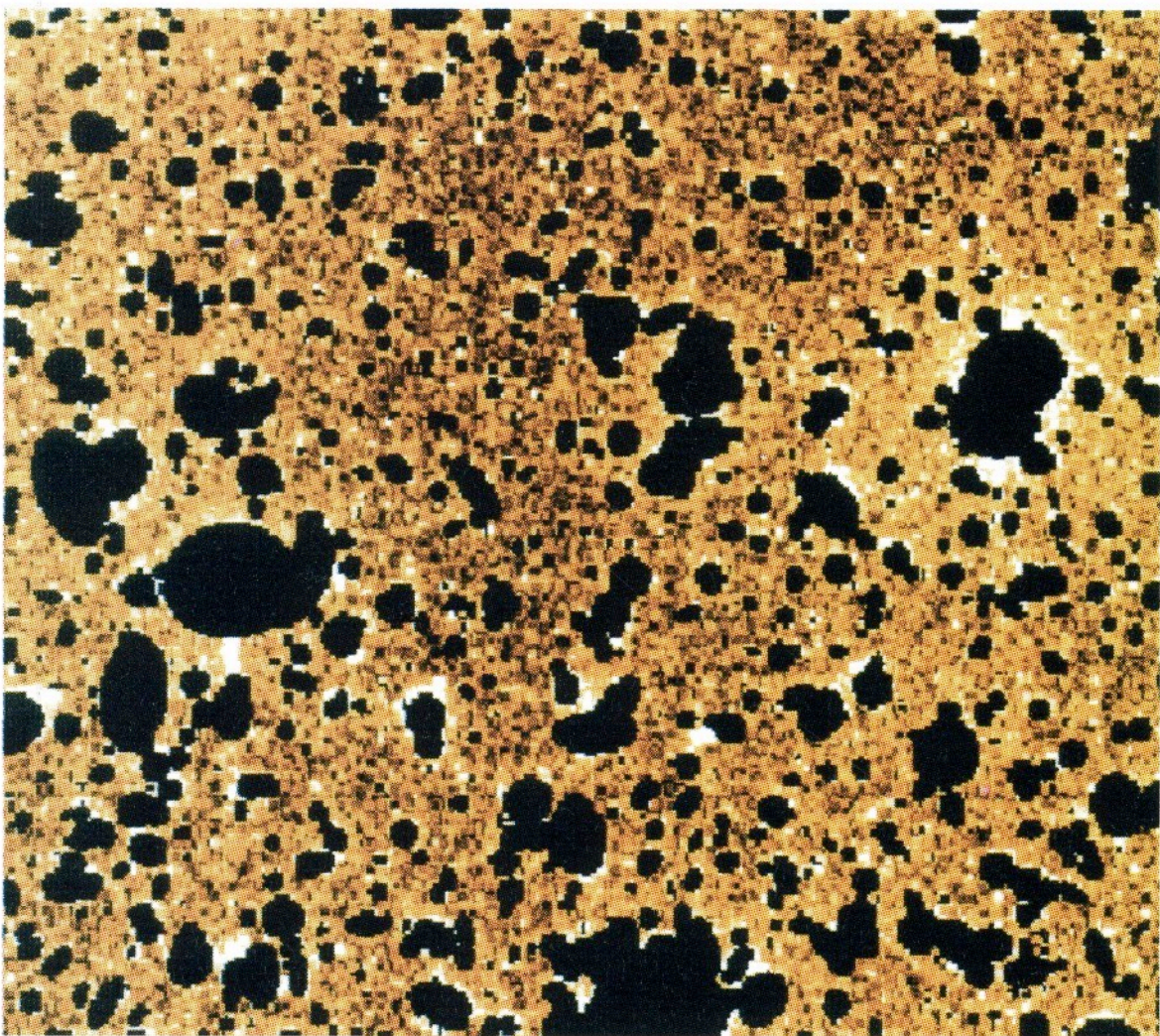
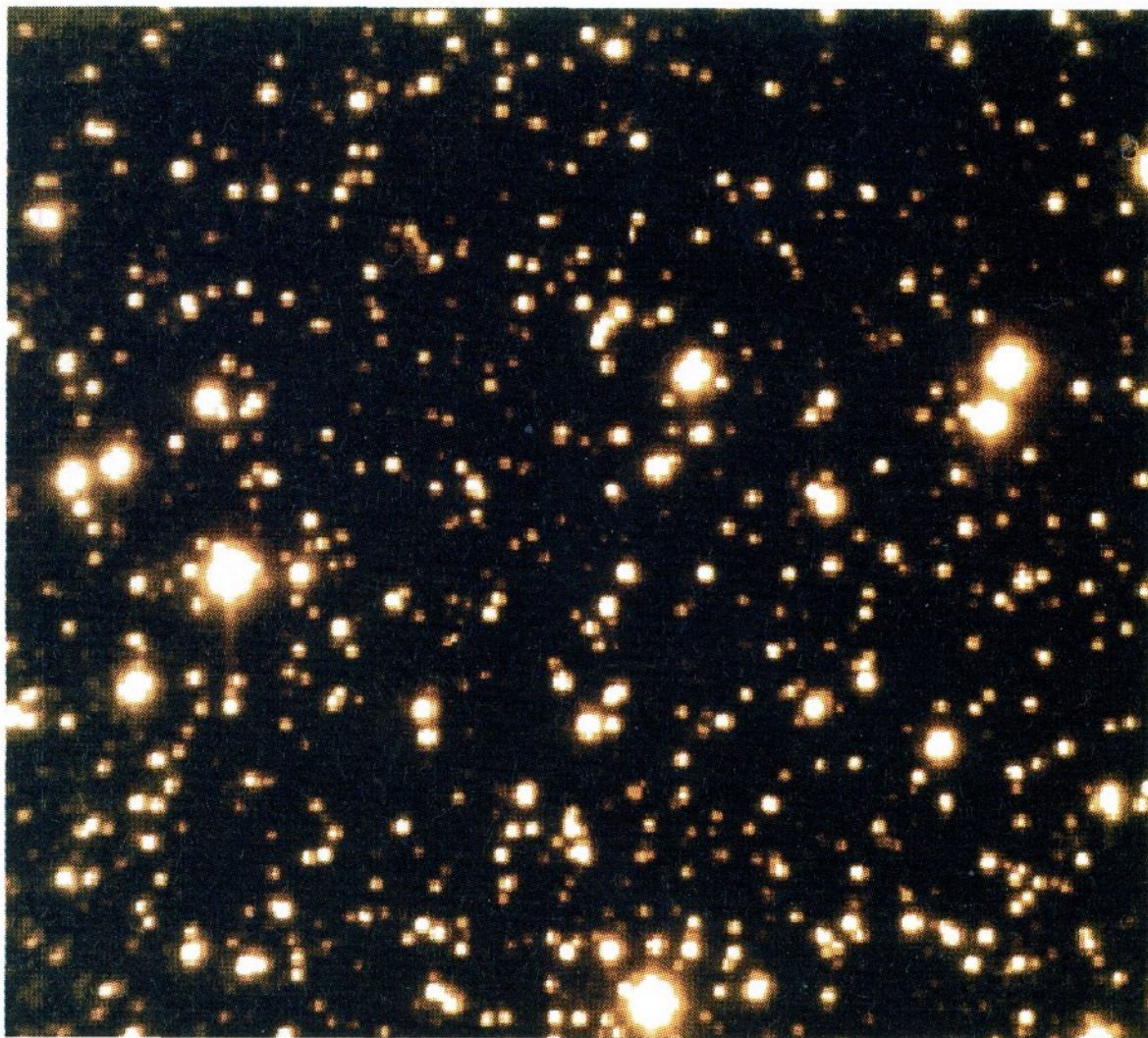


Figure 4. Information produced by PISAFIND can also be used by other Starlink packages. In this example, the regions occupied by the objects detected in the upper image have been removed using the KAPPA program ARDMASK. The result is shown in the lower image. This makes the completeness of the detections obvious (840 objects were detected in the upper image, using a 2.5 sigma threshold), and it also makes it easy to check the flatness of the image background.

This method might also be used before creating flatfields from "dithered" images. The object measurements made by PISA can also be imported into the catalogue manipulation package CURSA.

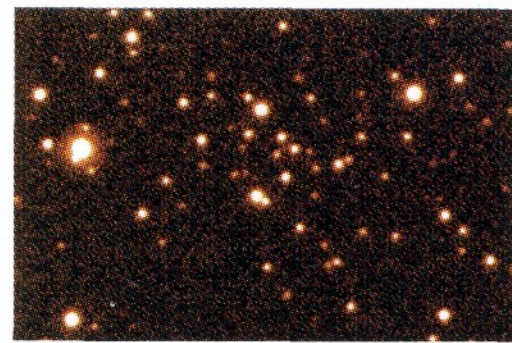


Figure 3. The results from PISAFIND can be used by PISAGEN to generate model data to which noise can be added. This is useful for testing purposes. The picture above shows such an image generated from the object detections in Figure 1.

Other PISA programs

PISAPLOT – plots the results of running PISAFIND as ellipses (e.g. Figure 1).

PISAFIT – determines the best fit of an algebraic model to stars.

PISAGEN – generates analytic objects (e.g. Figure 3).

PISAPEAK – creates a new set of measurements that show how star-like each object is.

PISAKKN – separates objects into two classes using a non-parametric test.

PISACUT – separates a file into two parts, given a threshold value for a specific variable.

PISAMATCH – matches object indices between files.

Help

PISA is described in *SUN/109*, available on paper or WWW at:

<http://star-www.rl.ac.uk/docs/sun109.htx/sun109.html>

PISA is supported by Peter Draper, who is available at:

P.W.Draper@durham.ac.uk



CURSA is a package for manipulating astronomical catalogues and similar tabular data. It lets you examine, list, sort, pair and select subsets from catalogues.

Although CURSA is intended primarily for use with astronomical catalogues, it can also be used with other tabular data, such as tables of private astronomical results, or even data which are entirely non-astronomical.

Browsing the sky

The main component of CURSA is *xcatview* – a powerful and flexible browser for examining catalogues.

It lets you:

- * List columns and auxiliary information.
- * Select subsets according to some criteria (e.g. all the objects brighter than some limiting magnitude).
- * Compute new columns from existing columns (e.g. the V magnitude when only the B magnitude and B-V colour are tabulated).
- * Save subsets (including new columns) as either text files suitable for printing or as new catalogues.

It has a mouse-driven *point-and-click* graphical interface, making it easy to learn and use. Alternatively, it can be driven from a simple script, enabling you to do “batch” work.

Sample output

Figure 1 shows some example output generated by *xcatview*. In this case the program was used to extract a subset of the Catalogue of Quasars and Active Galactic Nuclei due to M.P. Veron-Cetty and P. Veron. The subset comprises all quasars brighter than nineteenth magnitude and with a redshift greater than three – a total of 74 objects out of 4234.

The figure shows the first screen of objects – the buttons allow any desired part of the subset to be displayed.

Seq num	Name	RA	DEC	V	Redshift
1	PKS1935-692	19:35:11.8	-69:14:52	18.80	3.170
2	*	6:42:13.4	-50:38:07	18.50	3.090
3	*0201-504	2:01:52.3	-50:26:48	18.00	3.070
4	Q 2204-408	22:04:33.1	-40:51:38	17.57	3.170
5	*Q 0324-407	3:24:29.3	-40:47:11	17.60	3.056
6	*Q 2348-4025	23:48:48.0	-40:25:00	18.60	3.310
7	*Q 0130-403	1:30:50.2	-40:21:51	17.02	3.015
8	*	22:27:38.0	-39:28:33	18.80	3.450
9	*Q 0351-390	3:51:30.9	-39:04:46	17.80	3.010
10	Q 0420-388	4:20:29.9	-38:51:50	16.92	3.120
11	*Q 0347-383	3:47:53.7	-38:19:30	17.30	3.230
12	*Q 0140-306	1:40:37.5	-30:38:50	18.50	3.130
13	*0055-2659	0:55:32.6	-26:59:26	17.20	3.670
14	*0105-2634	1:05:48.2	-26:34:20	17.30	3.505
15	*0042-2627	0:42:06.2	-26:27:43	17.00	3.400
16	*Q 0000-2619	0:00:00.1	-26:19:00	18.00	4.111
17	*UM 678	2:49:25.5	-22:12:37	18.40	3.202
18	*UM 672	1:32:14.9	-19:47:19	18.70	3.130
19	*UM 669	1:02:49.7	-19:02:18	18.30	3.035
20	*UM 679	2:49:29.8	-18:26:21	18.60	3.205
21	PKS 2126-15	21:26:26.7	-15:51:51	17.30	3.275

Figure 1. Example output from *xcatview* listing a subset selected from the Veron-Cetty and Veron quasar catalogue. The row of menus across the top of the window control the operation of *xcatview*. The main portion of the window shows the first screen of objects in the selected subset. The row of buttons about three-quarters of the way down the window control navigation through the subset, allowing any part to be displayed. Finally, informational, warning and error messages are displayed towards the bottom of the window.

Figure 2 (overleaf) shows the same subset plotted as a Hammer-Aitoff all-sky projection. The data were saved as a text file and then plotted using Starlink's PONGO package (other plotting packages could also have been used).

Preparing for observations

Another use for *xcatview* is to prepare for an observing programme.

If you were planning to observe a certain type of object, such as a planetary nebula, you could obtain a suitable catalogue and then use *xcatview* to find nebulae which matched your constraints.

These might include the range of RA and Dec observable during your observing time, the limiting magnitude of the telescope you were going to use, and any specific criteria relevant to your proposed investigation or instrumentation.

Other applications

CURSA contains several other applications in addition to *xcatview* – three of the most important are:

- * *catsort* – sorts a catalogue into ascending or descending order on a specified column.
- * *catpair* – pairs two catalogues, objects being matched if they have similar celestial coordinates.
- * *catheader* – lists the header information for a catalogue.

CURSA

is a slightly contrived acronym for

Catalogue Utilities for Reporting, Selecting and Arithmetic.

It is borrowed from the common name for β Eridanus.

Centre $\alpha=12^h$ $\delta=0^\circ$

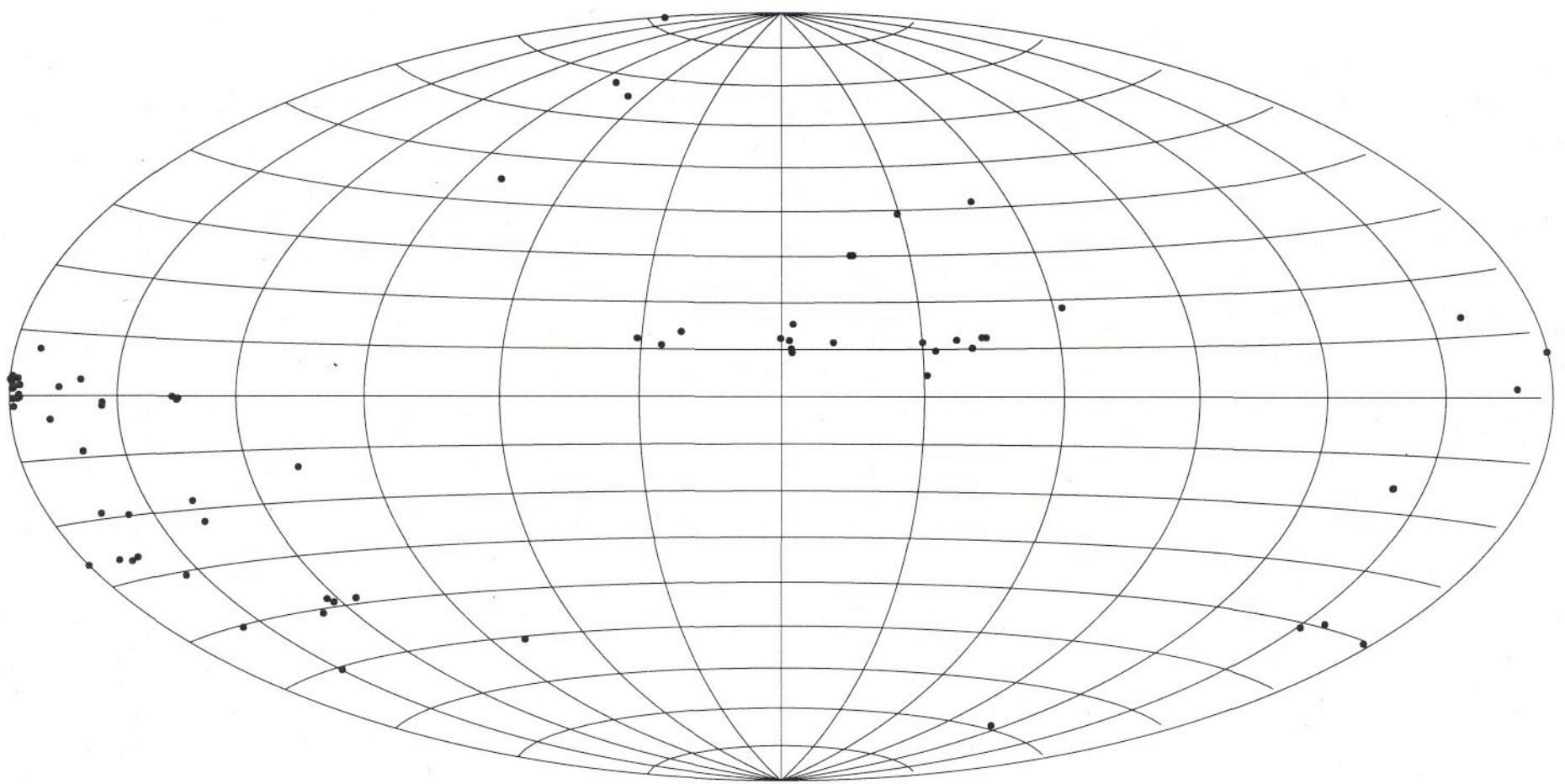


Figure 2. An all-sky Hammer-Aitoff projection of quasars brighter than nineteenth magnitude and with a redshift greater than three, extracted from the Veron-Cetty and Veron quasar catalogue with xcatview and plotted with PONGO.

Finding catalogues

Catalogues are ubiquitous in astronomy – lots of computer-readable ones are available, sometimes with millions of entries, and they provide a wealth of information on most branches of astronomy.

The standard FITS tables format is becoming an increasingly common one for catalogues. CURSA reads this format, giving immediate and convenient access to a large number of catalogues.

Several CD-ROMs containing catalogues in FITS tables format have been distributed, such as:

- * The extremely useful *Selected Astronomical Catalogs* series containing a collection of widely used catalogues.
- * The *HST Guide Star Catalog* (GSC).

Most Starlink sites will have at least some of these CD-ROMs.

Collections of catalogues are maintained and distributed by:

- * US Astronomical Data Center (ADC) at the NASA GSFC.
- * Centre de Données astronomiques de Strasbourg (CDS).

These places are increasingly making their data available in FITS format.

Many catalogues are not in FITS format, but they can usually be converted to it. Examples are tables produced by fast microdensitometers operated as national facilities in the UK (e.g. SuperCOSMOS at ROE), old data from the original COSMOS machine, and private catalogues.

CAT library

CURSA is augmented by the CAT subroutine library for manipulating catalogues and tables. This makes it easy to write your own programs to do specialised tasks not covered by CURSA. Programs written using CAT are fully compatible with CURSA applications, which also use CAT.

Help

CURSA is described in *SUN/190*, available on paper or the WWW at:

<http://star-www.rl.ac.uk/docs/sun190.htx/sun190.html>

It also has its own "home page" available at:

<http://www.roe.ac.uk/acdwww/cursa/home.html>

This includes answers to frequently asked questions and more information on where to find catalogues.

CAT is described in *SUN/181*, available on paper or the WWW at:

<http://star-www.rl.ac.uk/docs/sun181.htx/sun181.html>

CURSA and CAT are supported by Clive Davenhall, who is available at:

acd@roe.ac.uk



Starlink Software Collection

FIGARO

FIGARO is a general purpose data reduction system. Many people find it ideal for reducing spectroscopic data, but it also has powerful image and data cube manipulation facilities.

Starlink recommends it as the most complete spectroscopic data reduction system in the Starlink Software Collection.

The five figures display examples of data analyses done using FIGARO.

Applications

Examples of its use include:

- * Absorption line analysis.
- * Flat-fielding.
- * Spectrophotometric flux calibration.
- * Generation and application of a spectrum of extinction coefficients.
- * Wavelength calibration.
- * S distortion correction.
- * Extraction of fibre spectra from images.
- * Gaussian line fitting.
- * Fourier transformation and filtering.
- * Echelle data reduction.
- * Aperture photometry.

Platforms

- * Solaris & Digital Unix.
- * Linux.

Origins

FIGARO has been built up over many years as a result of collaboration between the following organisations:

- * Starlink.
- * Anglo-Australian Observatory.
- * California Institute of Technology.
- * University of New South Wales.
- * Mt Stromlo & Siding Springs Observatory.

It also contains many contributions from its users around the world.

Help

FIGARO is described in SUN/86, available on paper or WWW at:

<http://star-www.rl.ac.uk/docs/sun86.htx/sun86.html>

FIGARO is supported by Martin Clayton, who is available at:

mjc@star.ucl.ac.uk

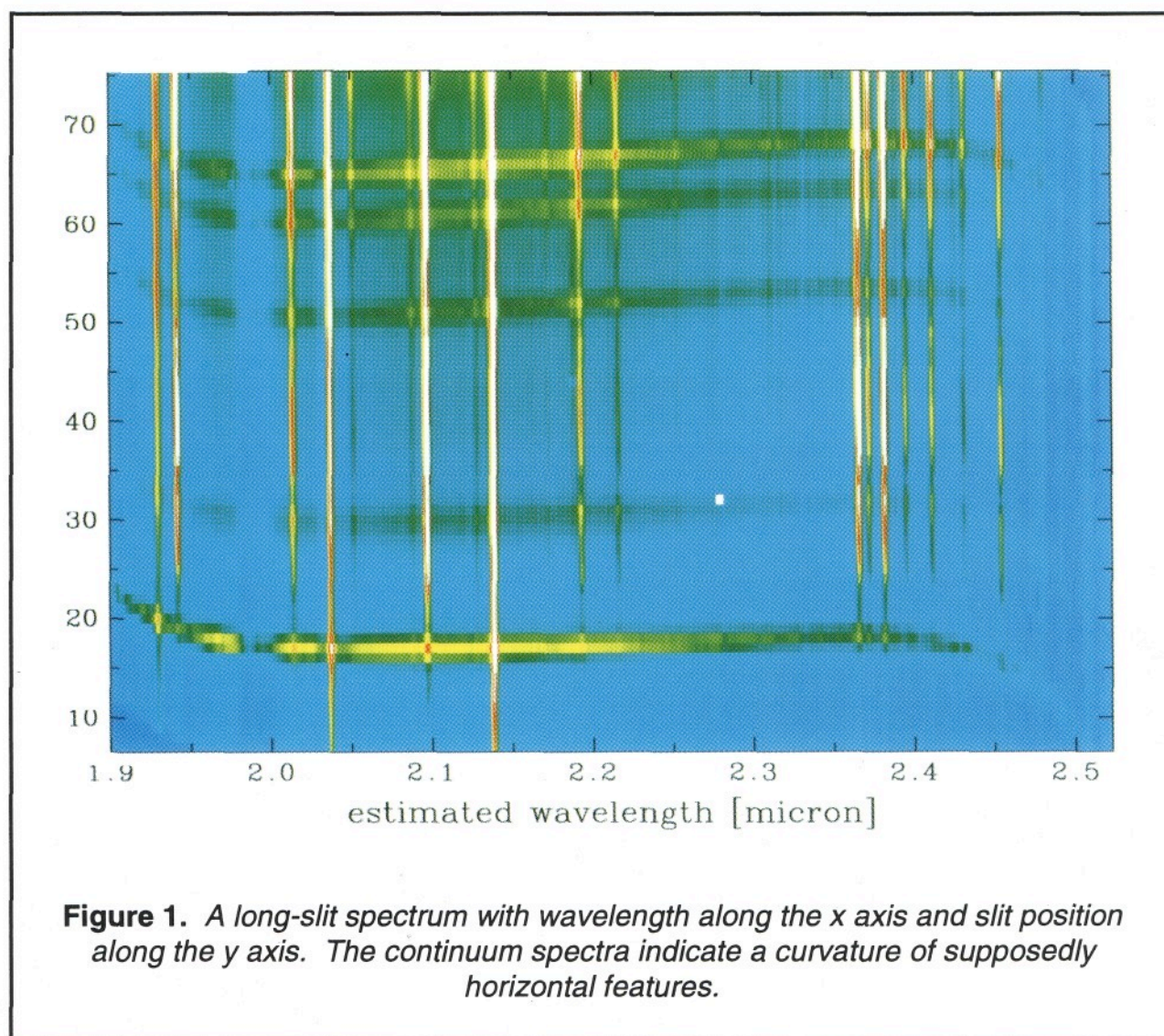


Figure 1. A long-slit spectrum with wavelength along the x axis and slit position along the y axis. The continuum spectra indicate a curvature of supposedly horizontal features.

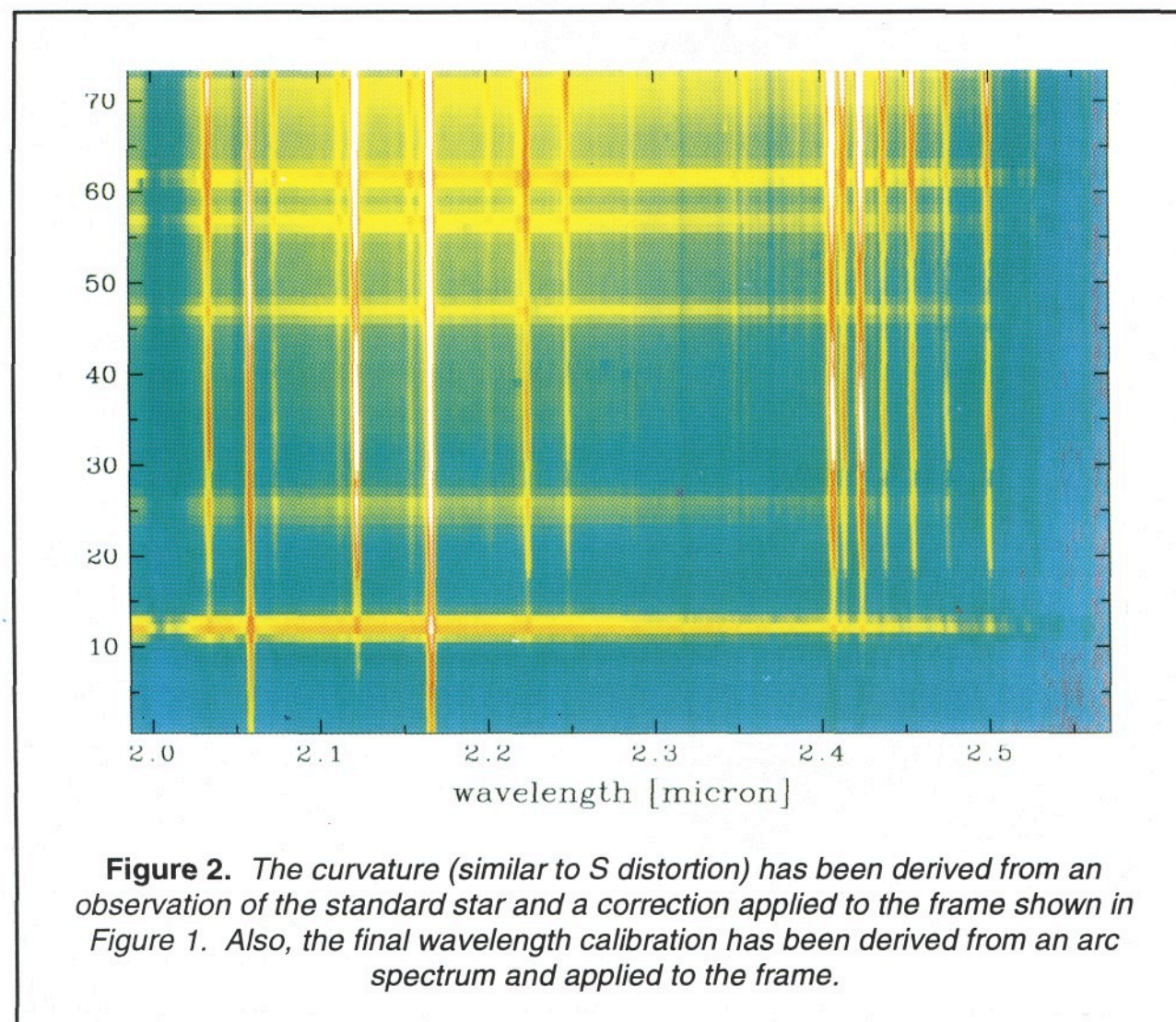


Figure 2. The curvature (similar to S distortion) has been derived from an observation of the standard star and a correction applied to the frame shown in Figure 1. Also, the final wavelength calibration has been derived from an arc spectrum and applied to the frame.

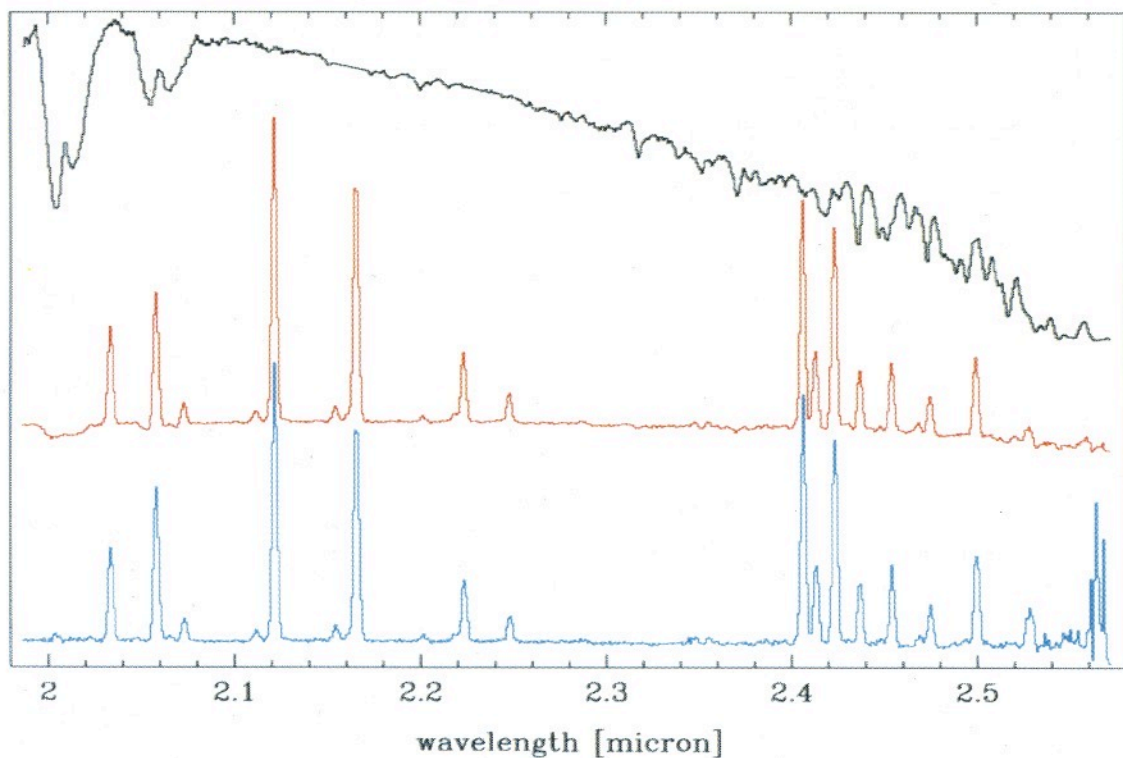


Figure 3. (Left) Using observations of a standard star (black) and object (red), the latter can be calibrated in physical rather than detector-specific units. Most absorption features in the standard spectrum are due to the Earth's atmosphere and affect the object spectrum in the same way. Their inclusion in the standard spectrum serves to eliminate them in the calibrated object spectrum (blue). This shows a constant finite continuum in addition to a large number of emission lines.

Figure 4. (Right) Example of an analysis of the Brackett-gamma absorption line in a bright star. The ragged line is the observed spectrum. The two depressions are absorption lines in the otherwise continuous spectrum of the star. First, three wavelength ranges were marked as continuum, then the smooth curve was fitted as a third-order polynomial. The absorption lines were then analysed. Among the results are the equivalent width of the line, its area, and a measure of its asymmetry.

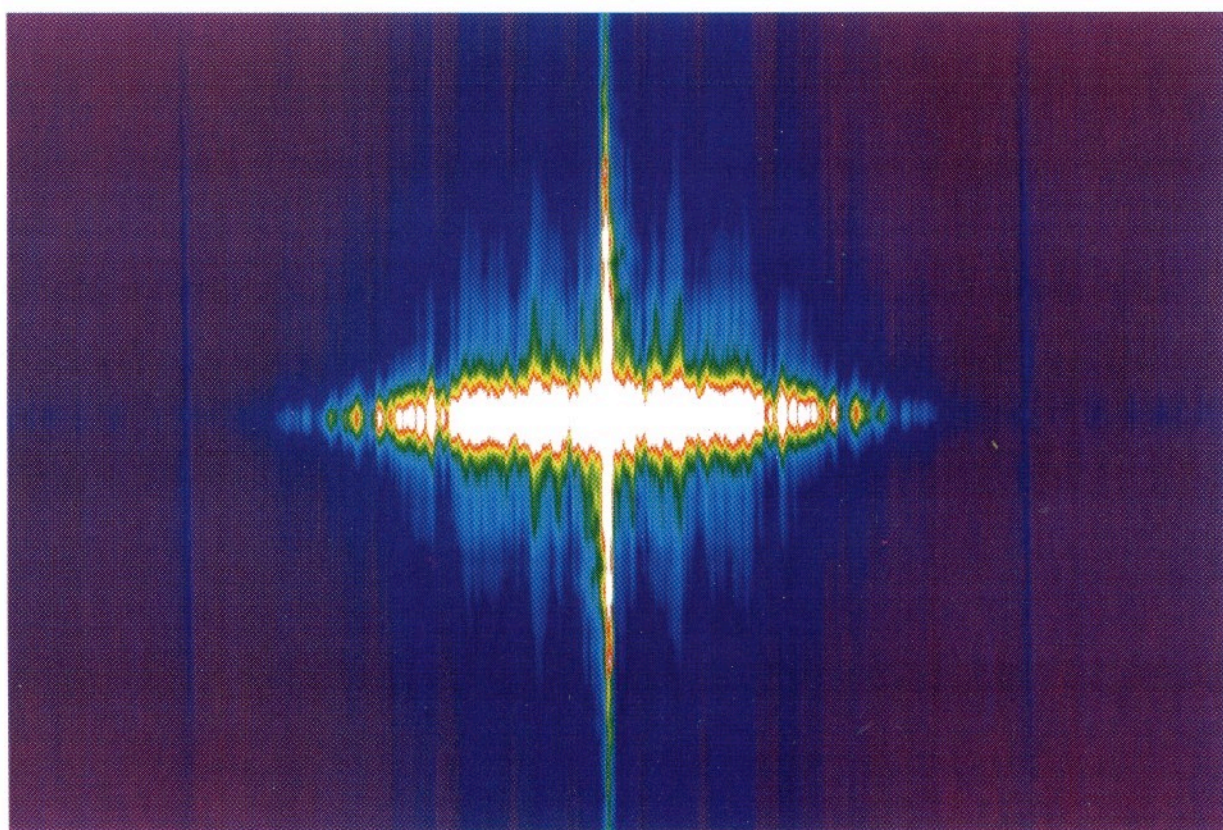
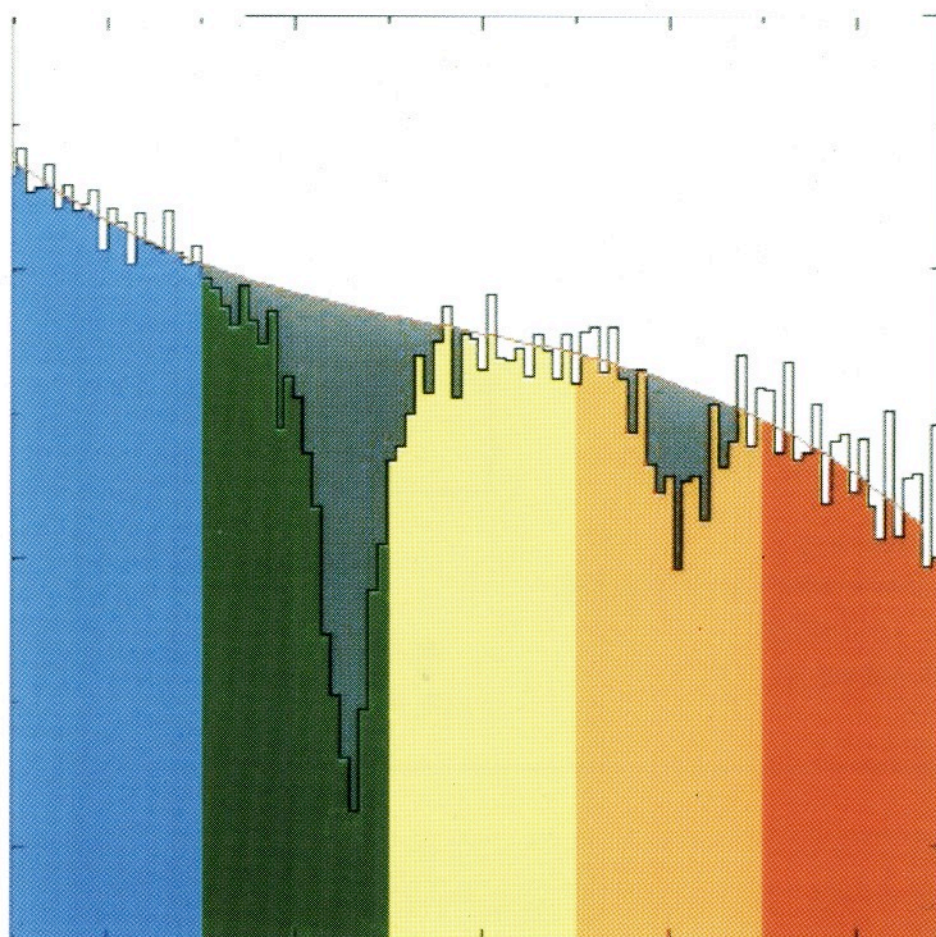


Figure 5. (Left) The Fourier transform of the image shown in Figure 1. In a Fourier transform, the information is presented in a different way: it is sometimes used as an intermediate stage to filter out certain features in the data, such as noise or periodic disturbances. A Fourier transform typically shows structure in the centre and little signal on the edges. What signal there is on the edges corresponds to noise (statistical uncertainties) in the original image. Strong peaks away from the centre indicate a stripy pattern in the original.



Starlink Software Collection

KAPPA

KAPPA is a package of about 180 general-purpose commands for *image processing* and *data visualisation*. It complements more specialised astronomical packages which do not themselves contain these basic facilities.

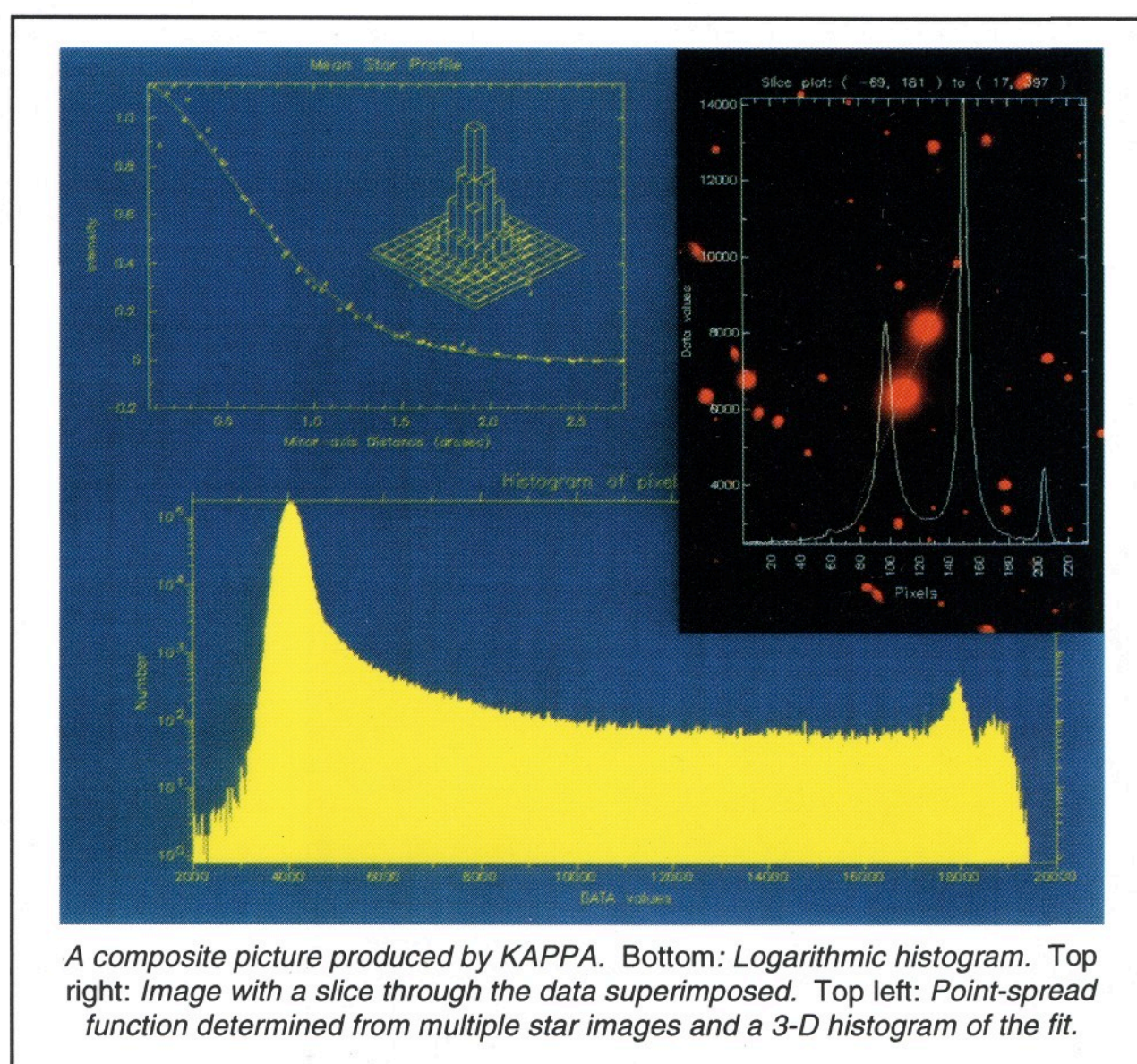
Applications

Application areas supported include:

- * Arithmetic, including expressions using images and co-ordinates.
- * Pixel and region editing, masking and flagging of missing data.
- * Regridding, using a variety of geometrical transformations.
- * Filtering, convolution and deconvolution.
- * Change of dimensionality, origin and orientation.
- * Fitting of surfaces and point-spread functions.
- * Detail and contrast enhancement.
- * Generation of test data.
- * Statistics and inspection of data values.
- * Locating centroids of features.
- * Flexible line graphics and image display.

General Features

KAPPA can cope with statistical error information, data-quality masks, missing data and coordinate axes.



A composite picture produced by KAPPA. Bottom: Logarithmic histogram. Top right: Image with a slice through the data superimposed. Top left: Point-spread function determined from multiple star images and a 3-D histogram of the fit.

Subsets and supersets of data may also be selected.

Many commands can process data arrays with between 1 and 7 dimensions, while others are designed specifically for use on spectra and/or images. Processing of all integer and floating-point data types is supported.

KAPPA reads and writes data in Starlink's NDF format as well as in other image formats such as FITS, IRAF and GIF. Drivers for new formats are easily installed.

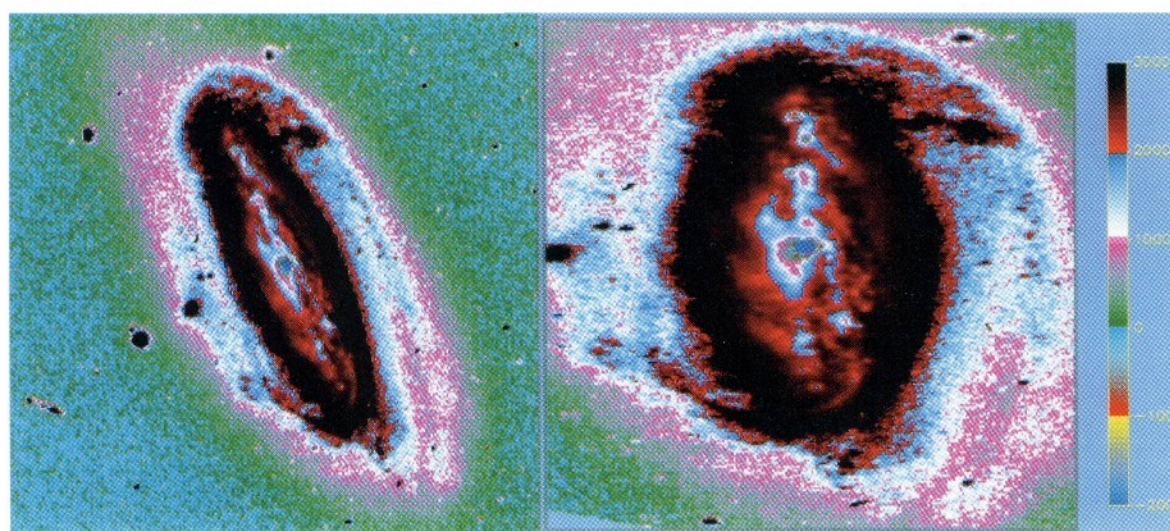
Command Languages

KAPPA normally operates from the Unix C-shell (and variants) or the ICL command language, but it may also be invoked from other scripting languages like tcl and perl as well as from graphical interfaces.

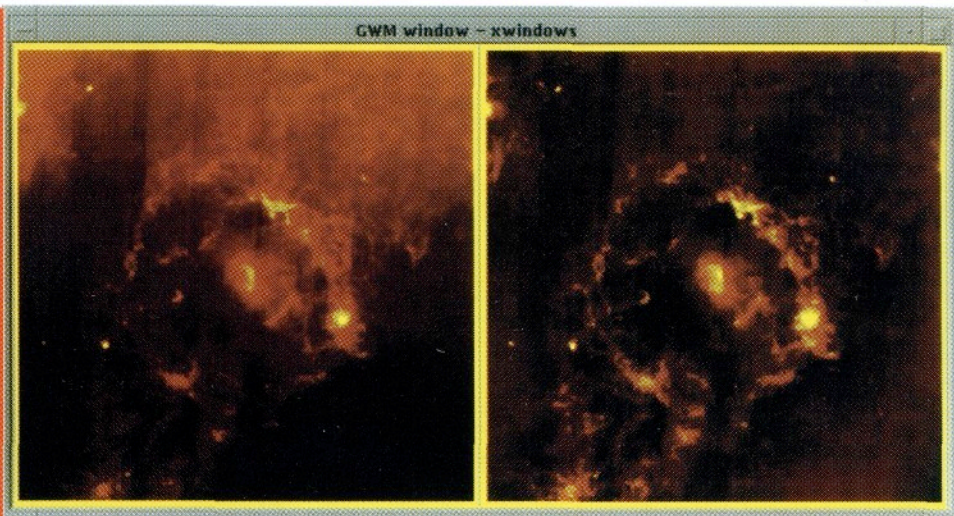
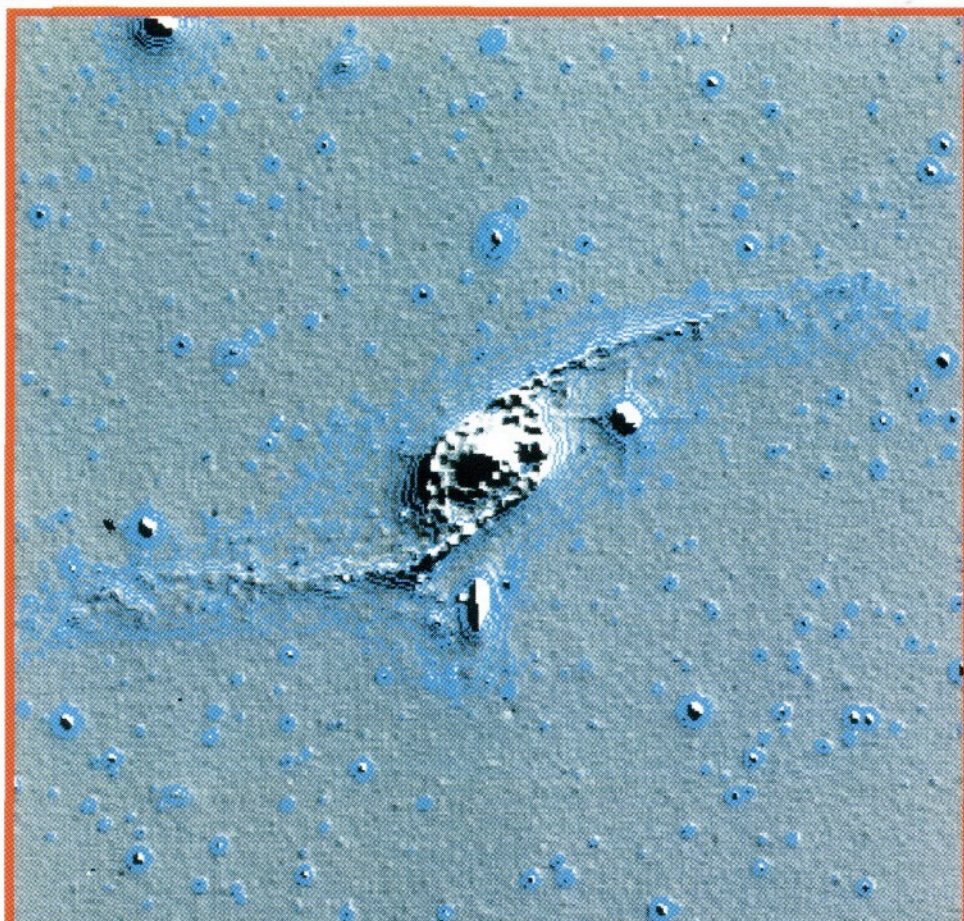
Documentation

The 450-page manual contains detailed descriptions of the commands and their parameters, with many examples. It includes general information, such as how to write C-shell scripts, and has several tutorials illustrating techniques like data masking.

A quick-reference card is available which summarises the commands and how to use their parameters.



Left: A composite false-colour image of the Seyfert galaxy NGC 7552 showing simultaneously the bright nucleus and inner spiral arms, as well as the faint outer arms. Right: the image on the left has been rotated and stretched laterally by KAPPA to appear as if seen face-on.



This montage of images shows examples of data processing using KAPPA.

Top Right

A region of sky in Orion observed by IRAS at 60 microns. On the left is the raw image. On the right, the background has been flattened and the contrast enhanced.

Top Left

A bas-relief plot of NGC 6872 with outer contours overlaid.

Centre Left

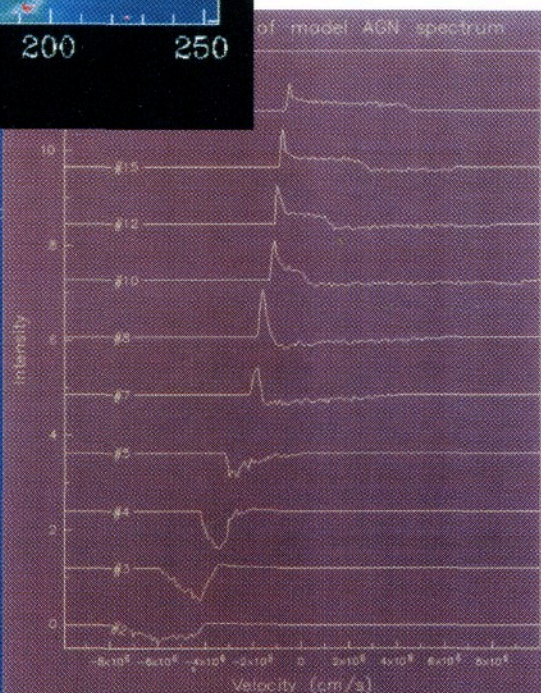
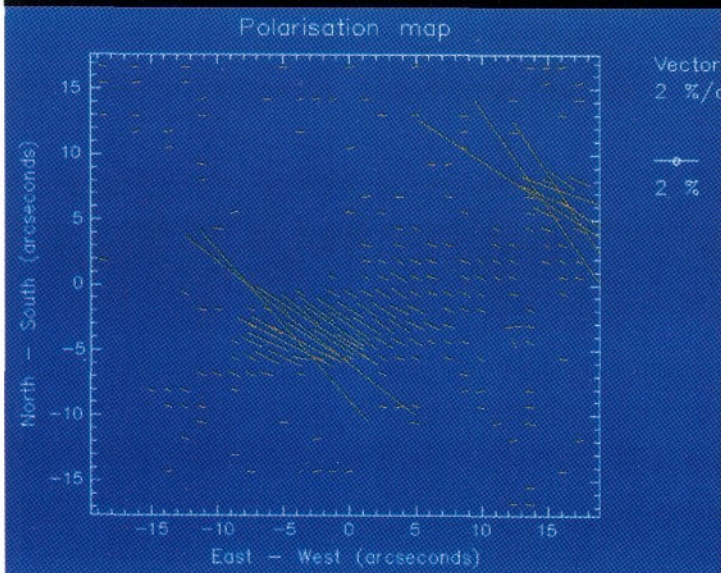
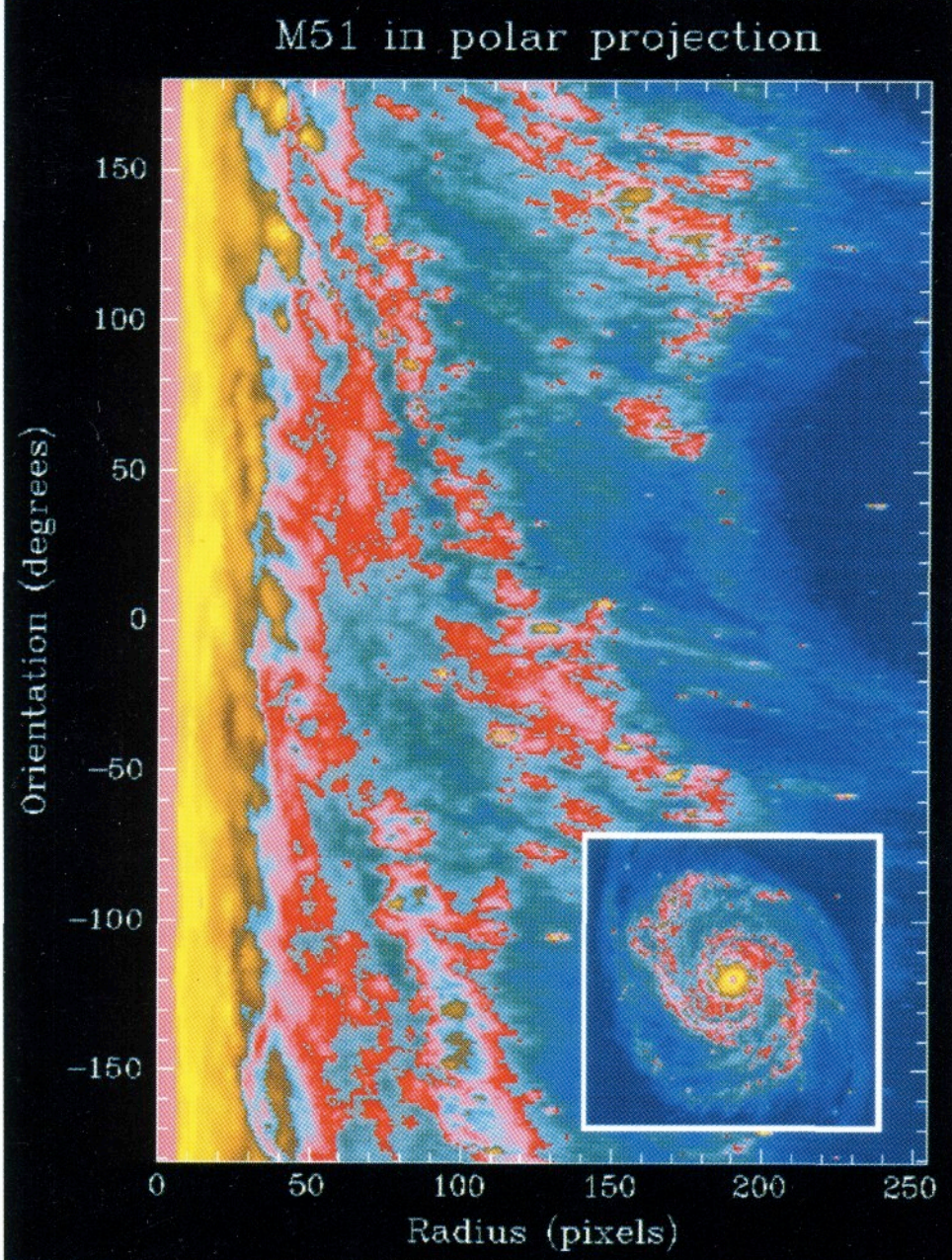
A CCD image of M51 shown in polar projection and displayed in false colour after histogram equalisation. The inset shows the galaxy before resampling.

Below Left

A polarisation map computed and displayed using KAPPA, with low signal-to-noise data removed. (Courtesy of Jim Emerson, QMW)

Below Centre

A two-dimensional model AGN spectrum showing the variation of a broad emission line with time. Line numbers are in days. (Courtesy of Paul O'Brien and Mike Goad.)



Help

KAPPA is described in SUN/95, available on paper or WWW at:

<http://star-www.rl.ac.uk/docs/sun95.htx/sun95.html>

KAPPA is supported by Malcolm Currie, available at:

mjc@star.rl.ac.uk



Starlink Software Collection

GAIA

GAIA is a **graphical image display and analysis** tool.

It is more flexible than traditional image display tools as it can easily be extended, and can control existing programs. This sort of flexibility makes it an excellent tool for visually improving the ways in which astronomers work with their data.

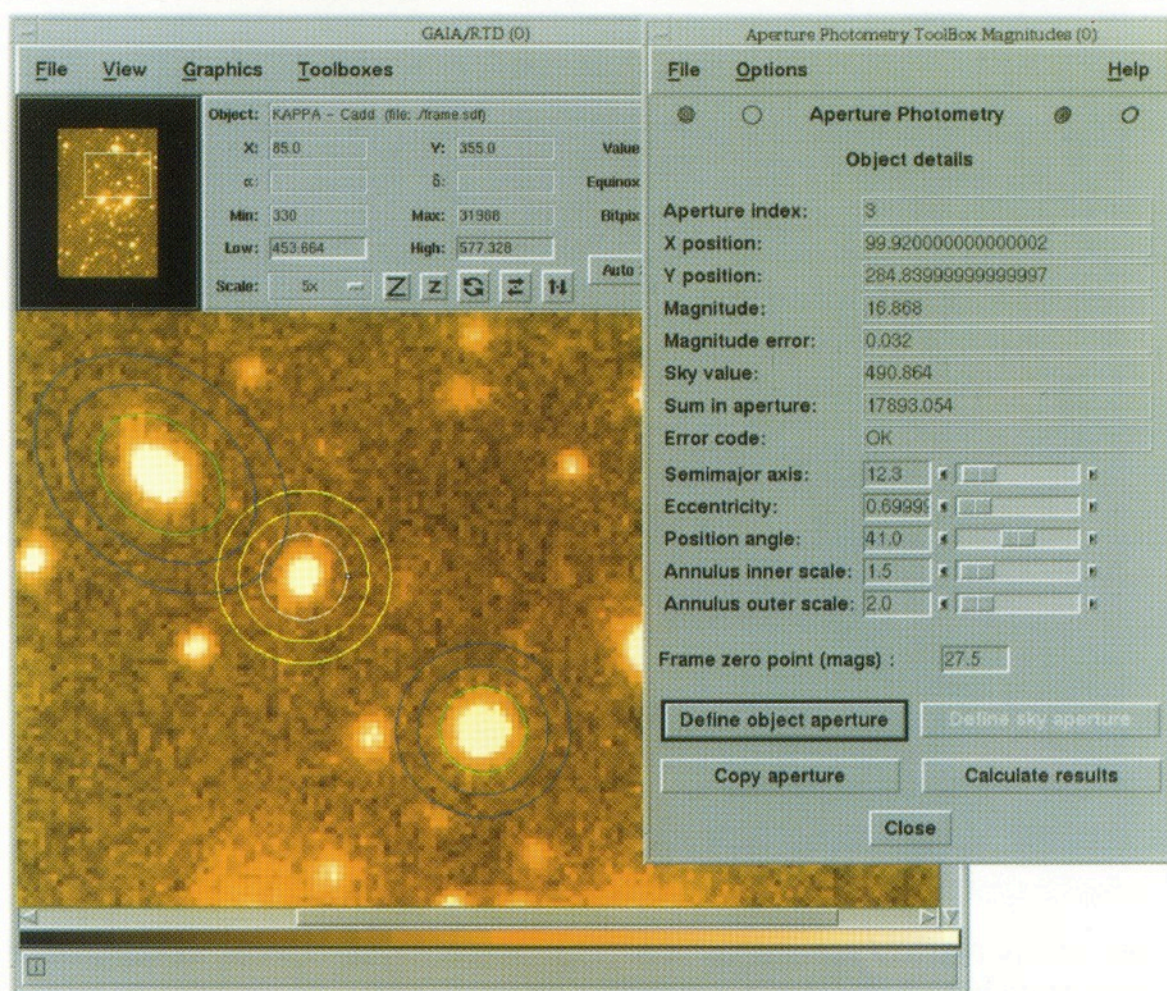
The initial version (March 1997) showed some examples of such integrated programs (such as PHOTOM, which does aperture photometry). Typically, tasks of this kind are controlled in a well defined way using a *toolbox*.

What does it do?

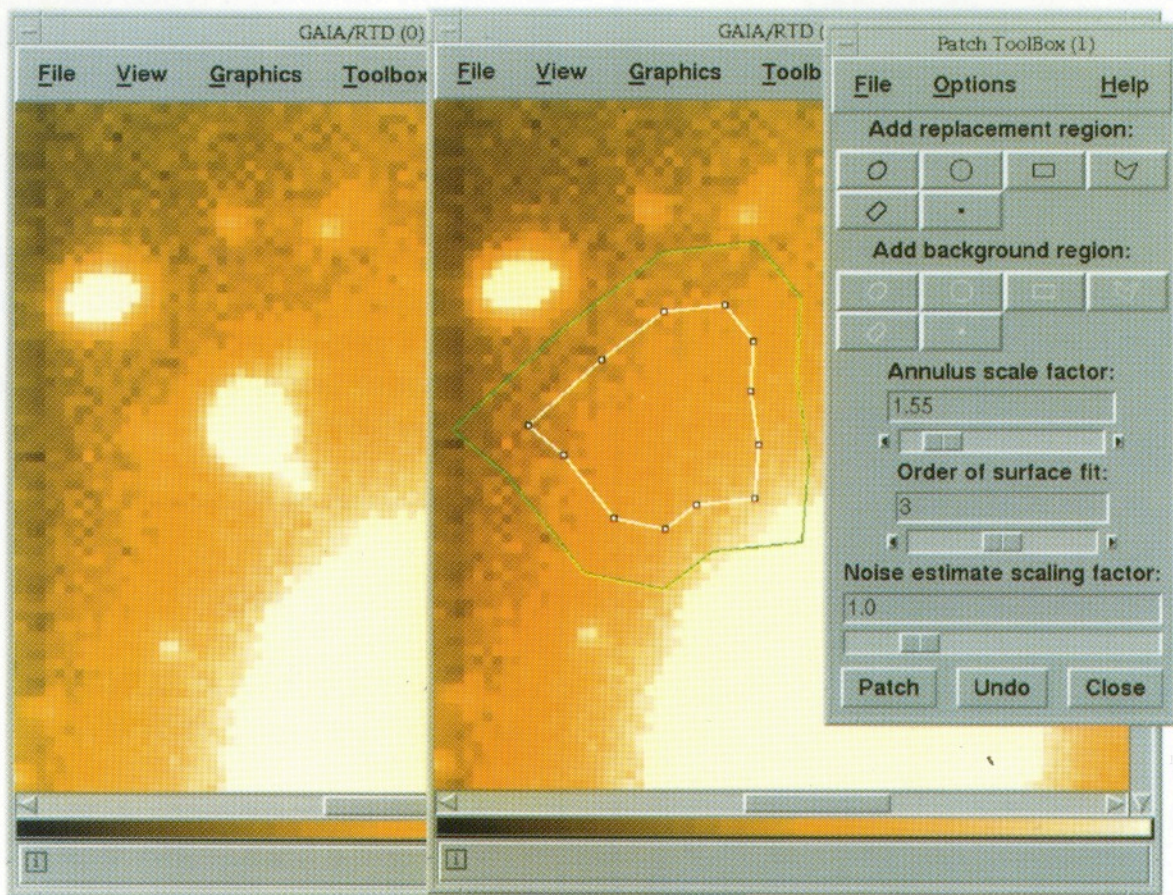
Among the many functions that GAIA offers are the following:

Aperture photometry

A highly interactive environment for controlling the positions, sizes, and orientations of circular and elliptical



This shows GAIA with the **photometry toolbox** in action. The apertures it creates can be elliptical or circular. You can also have sky regions in associated apertures rather than in the annuli. Many different apertures can be created at the same time. They can be picked up and moved about the image, resized, rotated, etc. Clicking on an image shows the measurement associated with it (naturally you can save and restore all the measurements using text files).



This shows GAIA in another configuration (the controls for zooming and showing the data values etc. are now in another window that is not visible). It is shown **patching an image** - the left image is the original; the right image is the result of replacing the region within the white polygon by a fit to the data in the annulus about it (plus some noise). Using this tool, you can replace arbitrarily shaped parts of your image, using other arbitrary bits of it to define a fit.

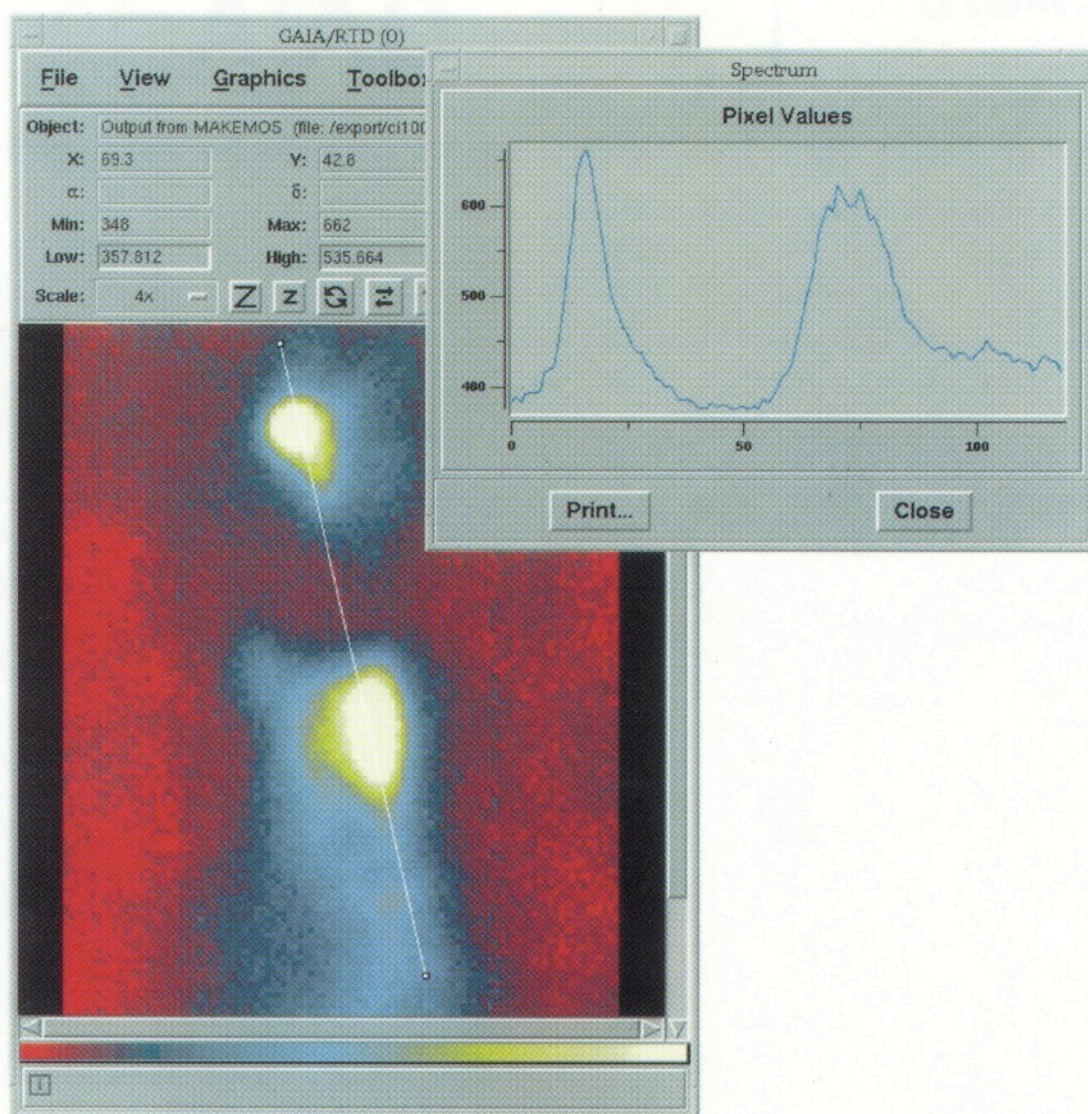
apertures, with sky estimates from annuli or other apertures. The measurements can be in either *instrumental magnitudes* or *mean counts*. (This is based on the Starlink PHOTOM package, see SUN/45).

Image patching

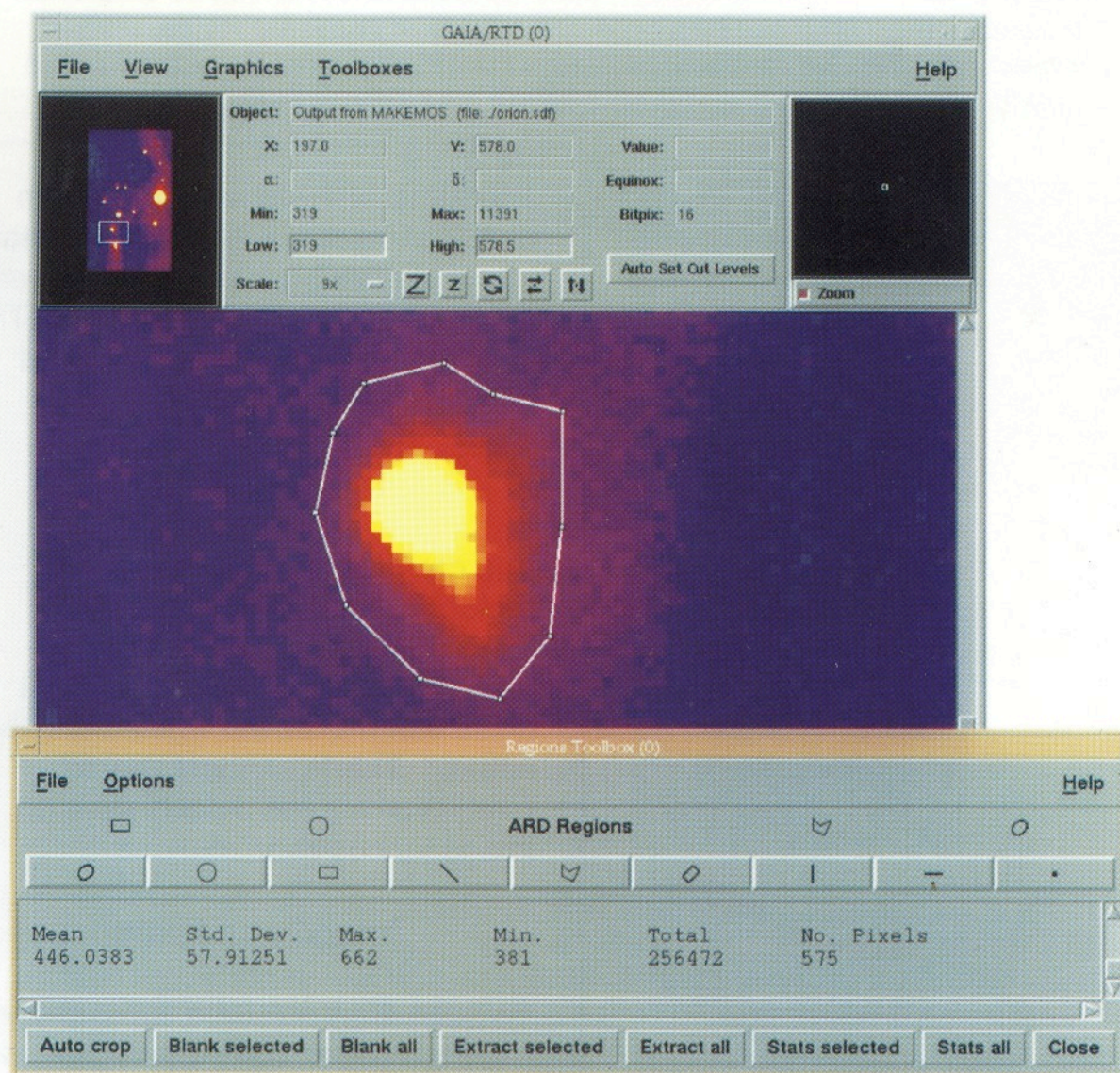
You can select arbitrarily shaped regions on an image and replace them with a surface fit to other regions, together with some artificial noise that makes the whole thing look natural. This is an ideal way to remove unwanted defects from an image for cosmetic reasons.

Image annotation

You can draw coloured lines, arrows, circles, ellipses, boxes, polygons, and text over your images, and then print a representation to a PostScript file. Line graphics are re-drawn at printer resolution (i.e. this is not a screen dump).



This shows GAIA in yet another configuration (the pan and zoom windows have been disabled). It displays a **slice through an object**. The slice can be moved around the image by dragging the little boxes on the ends of the line; the displayed data will be updated in real time.



This demonstrates GAIA being used to **estimate the statistics of an arbitrary region** of an image. Using this tool, you can also remove and extract such regions. Auto-cropping is useful for removing any large regions of blank pixels about an extracted image. Modified images are displayed in a new window, or in the existing window.

Image blinking

Allows you to blink through a stack of displayed images, or you can cycle through them slowly by hand.

Image regions

Lets you define arbitrarily shaped regions on your image. These can then be extracted or blanked-out, or you can see some simple statistics about them.

Real time slicing

A profile of the data along a line can be displayed and adjusted interactively. The slice is updated in real time.

Other functions

Many other image processing functions are provided, such as panning, zooming, colour table manipulation, display of multiple images, and continuous data and position readout (for R.A. and Dec if your images have suitable FITS WCS headers). Images can also be printed out on hard copy.

Data formats

GAIA will read NDF and FITS data files; in fact, since it uses NDF, it can read many other data types (such as IRAF and old FIGARO formats) using "on-the-fly" conversion.

History

GAIA is a derivative of the RTD (Real Time Display) tool, developed as part of the VLT project at ESO. RTD is free software under the terms of the GNU copyright.

Help

GAIA is described in SUN/214, available on paper or WWW at:

<http://star-www.rl.ac.uk/docs/sun214.htm/sun214.html>

GAIA is supported by *Peter Draper*, who is available at:

P.W.Draper@durham.ac.uk

Starlink forum

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Entry Name	Access	Unseen	Last New Note	Topics
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Systems-Management	P	0	04-Dec-1995 16:47	42
Maintenance	P	0	31-Oct-1995 16:42	2
Star-Forum	P	0	25-Oct-1995 11:06	8
Software-Links	P	0	28-Nov-1995 10:56	1
Programmers	P	0	01-Dec-1995 10:28	18
Questions-Answers	P	0	28-Nov-1995 10:09	1
Faults	P	0	30-Nov-1995 11:24	15

Problems? Try the [help page](#) or mail [Dave Rawlinson](#) ([dj@star.rl.ac.uk](mailto:djr@star.rl.ac.uk))

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