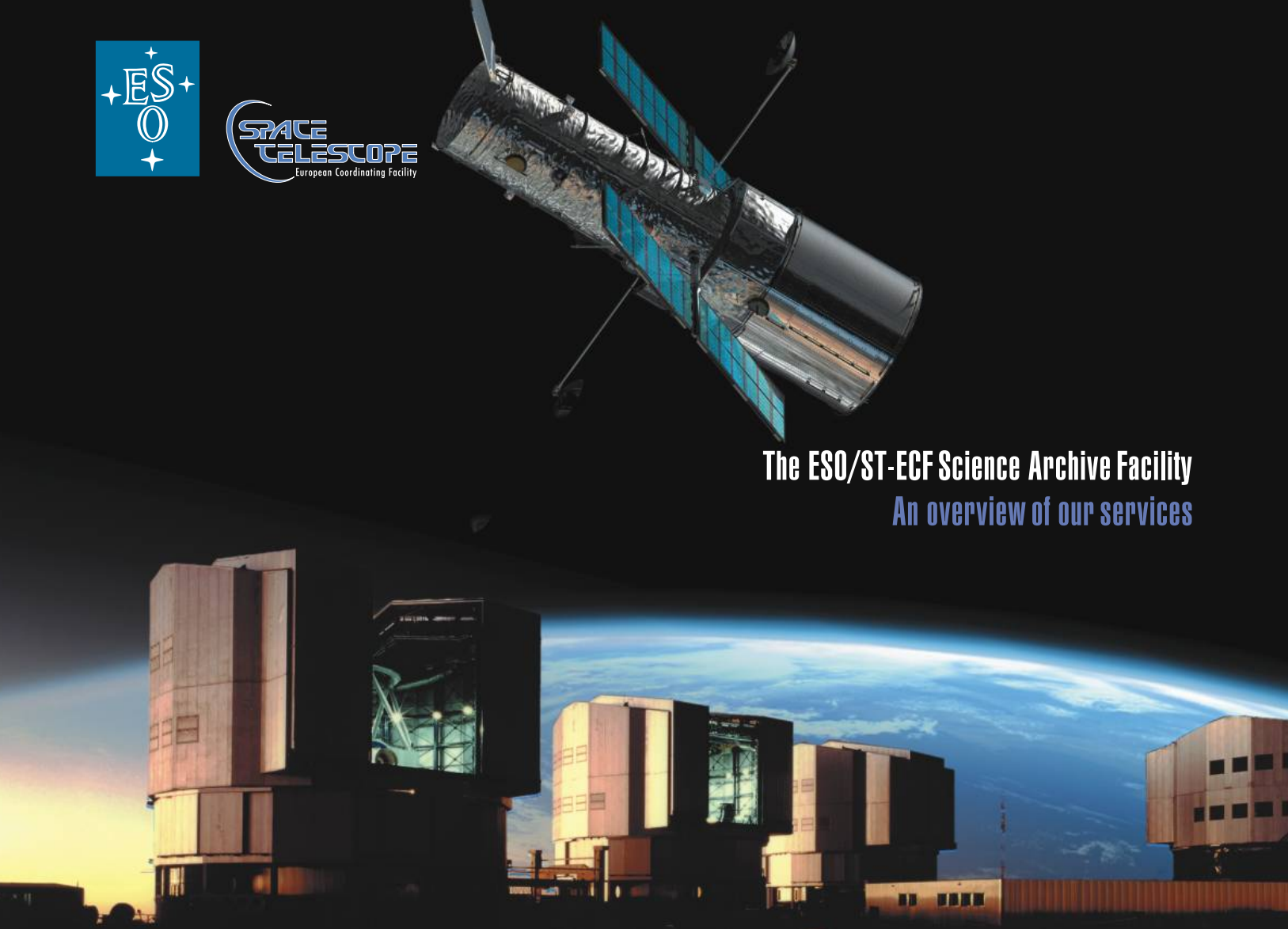


The ESO/ST-ECF Science Archive Facility

An overview of our services

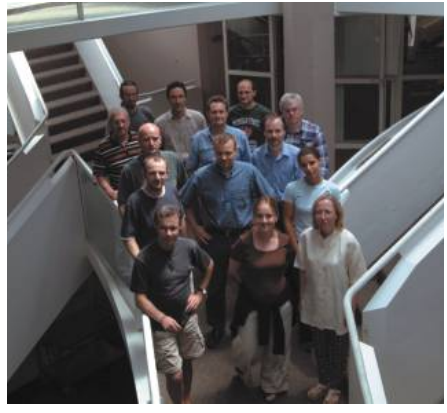
INDEX

AT THE FOREFRONT OF INNOVATION...

Over the last 12 years the European Southern Observatory and the Space Telescope-European Coordinating Facility (in collaboration with the Canadian Astronomy Data Centre, CADC) have implemented a number of innovative features for the ESO/ST-ECF Science Archive Facility that have since become part of a set of 'minimum requirements' for modern astronomical archive systems. These features include: previews, web interfaces to query the database, on-the-fly re-calibration, association of exposures, data mining and much more.

This brochure will describe some of the features of the Archive and the hidden technologies behind the public face. It is our hope that this information will make it easier for astronomers to use the Archive and its suite of tools.

Feedback on Archive topics: catalog@eso.org



The Operations Technical Support (OTS) group. The group manages databases, administers over 60 computers and performs all data operations.

How much?
The Archive currently holds about 21 TB of active HST and ESO data. In 2002 we distributed about 10 TB in total to users.

How long?
The Archive system was initially designed and built in the late 1980s. The first (HST) data became publicly available on January 1st, 1991. Since then VLT and Wide-Field Imager data have become available (late 1990's) and Archive usage has grown dramatically.

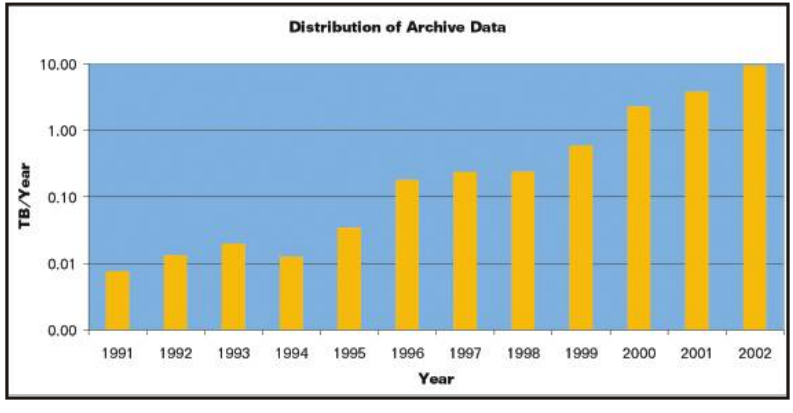
How many users?
3000 people are currently registered in the Archive. Each month, about 180 different Archive users and Principal Investigators (PIs) for ESO programmes receive data from us.

How many archive media?
The Archive currently comprises about 10,000 different media volumes. The recent, active media currently amount to 4500 DVD-R. The latter are located in 5 different DVD jukeboxes. We also have about 50 200GB magnetic disks in 8 different Linux nodes (the Next Generation Archive System).

Beno t Pirenne, head of the ESO/ST-ECF Science Archive Facility explains:

"The work in the Archive is multi-faceted and comprises, among other things: data input and distribution (manipulation of archive media), the preparation of Principal Investigator packages and overseeing the request queue. The work also includes first line user support and the management of our User Database. Larger projects include copying the entire active data holdings to a new media generation every few years. Technology develops fast, and we have to stay at the forefront! As to the future of the Archive, we should see ever more of the same type of activities. This means that to cope with an expected exponential growth in data volume without increasing the Archive staff significantly, we will have to seek and implement new technical solutions continuously. Efficiency is one of the watchwords for the future. This will have implications for our users as well, as the way data is accessed and distributed may change with time. New techniques are now being developed for the Virtual Observatory that will allow new ways of accessing your data."

Evolution (past, present and projected future) of the Archive holdings.



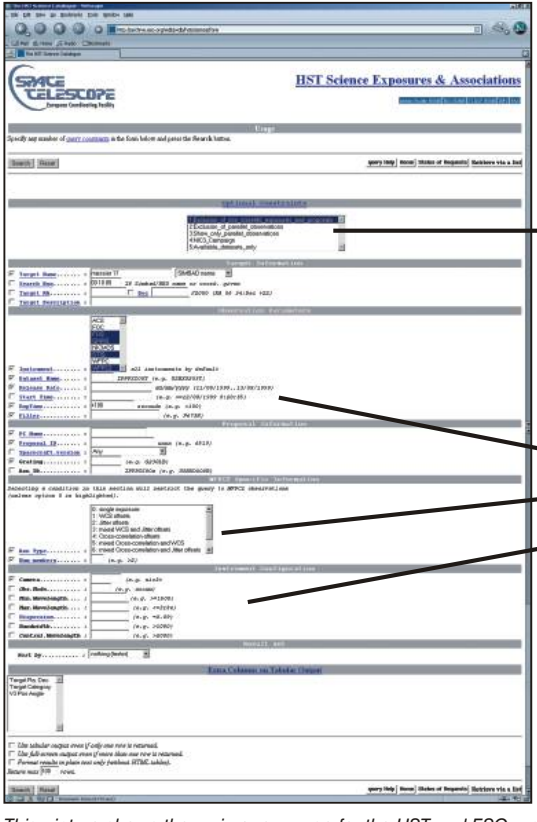
Evolution of the data distribution volume from the early days until now.

WEB QUERY (http://archive.eso.org/)

The Web interface used to query the database is how most users see the Archive. Numerous highly advanced tools and options are hidden behind the 'innocent' look of the web forms. It is possible to search for ESO or HST observations by object name or by searching for an area on the sky, and to combine queries for filters and exposure times. Choose from a number of data delivery options such as FTP, DVD-R, DLT.

Web services

It is possible to relate observations to ambient conditions at observatory sites, view preview images of some observations on-line, see observing programme schedules, query the calibration databases, and find information about observing proposals. Moreover, searching for observations made with all instruments in any of the supported archives can be carried out by Querator (http://archive.eso.org/querator).



Target
In the target section, specify the size of a search box and either object coordinates (equatorial, J2000) or a target name. For the target name it is possible to select whether the name given should be sent to the Simbad name server to be resolved into a coordinate or used to match against object names as recorded in the FITS headers of the frames in the Archive.

Observation Parameters
Specify parameters to query against the date and time when observations were carried out. This section gives access to values originally entered during the preparation phase of observations and contains important parameters such as exposure time, filters or grisms.

This picture shows the main query page for the HST and ESO archives. It allows the user to enter a number of parameters that will in turn be used to query the Archive database. For a better overview the form is organised into sections. Some details of these sections are described in the arrow texts. The parameters are converted into an SQL statement and sent to the database at the click of the "Search" button. The results are converted back into a HTML table.

ESO Observations available in the Archive

Paranal

FORS1	Imaging, Multi-Object Spectroscopy (MOS), long-slit spectroscopy, polarimetry (0.3 - 1 μm)
FORS2	Imaging, Multi-Object Spectroscopy (MOS), long-slit and echelle spectroscopy, polarimetry (0.3 - 1 μm)
ISAAC	Infrared imaging & long-slit spectroscopy (1-5 μm) UVES High resolution cross-dispersed spectroscopy (0.3 -1 μm)
NACO	High angular resolution imaging and spectroscopy (1 - 5 μm)
FLAMES	Multi-Object Spectroscopy (MOS) (fibre) & multi
IFS	(0.37 - 1 μm)
VIMOS	Wide field imaging, Multi-Object Spectroscopy (MOS), Integral Field Spectroscopy (IFS) (0.37 - 1 μm)
VINCI	Direct interferometry (1.5 - 2.5 μm)
MIDI	Mid-infrared long-baseline direct interferometry (8 - 26 μm)

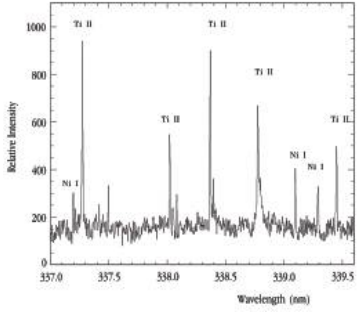
La Silla

EMMI	Imaging, Multi-Object Spectroscopy (MOS), long-slit, grating and echelle spectroscopy (0.3-1μm)
SUSI2	High resolution imaging (0.3 - 1.1 μm)
SOFI	Infrared imaging and spectroscopy (0.9 - 2.5 μm)
TIMMI2	Mid-infrared spectroscopy/imaging (3.6 - 20 μm)
HARPS	High-resolution spectroscopy (0.3 - 0.9 μm)
EFOSC2	Imaging, Multi-Object Spectroscopy (MOS), polarimetry (0.3 - 0.9 μm)
CES	High-resolution spectroscopy (0.3 - 1 μm)
WFI	Wide-field imaging, objective prisms (0.3 - 1 μm)

For ESO data, access to precise ambient and environmental data is also available.

ESO Archive data has public access after a one year proprietary period to Archive users with an affiliation within an ESO Member State, i.e., B, DK, F, D, I, S, CH, NL, P, UK and RCH.

A VLT/UVES 2-dimensional echelle spectrum.

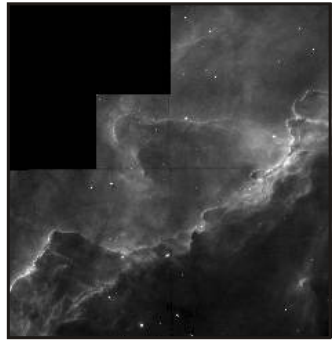


A small part of the near-ultraviolet spectrum of CN Leonis obtained with VLT/UVES.

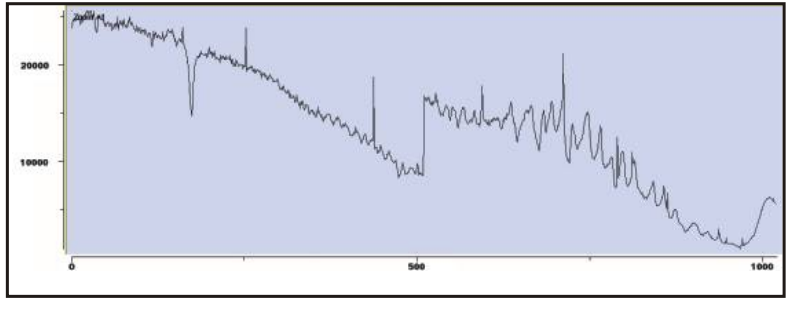
HST observations available in the Archive

ACS
WFPC2
STIS
NICMOS
FOC
FOS
GHRS
WFPC

HST Archive data has public access world-wide after a one-year proprietary period.



Messier 17 WFPC2 observation (individual chips stitched together as a mosaic).



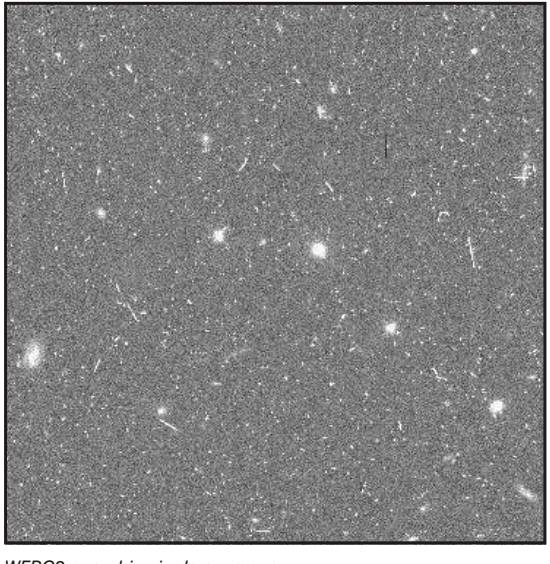
Raw STIS spectrum of the surroundings of Messier 17.

ASSOCIATION OF EXPOSURES

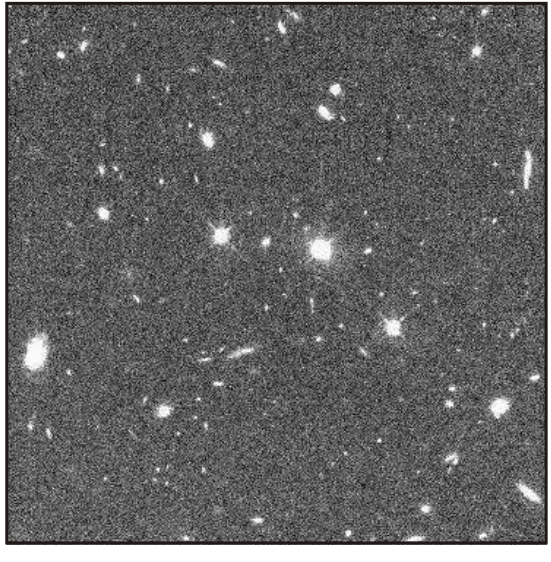
An optimal observing strategy addresses such diverse issues as cosmic rays, hot pixels, bad columns and spatial undersampling. Typically, for various technical reasons, many short exposures of the same target are preferred over one single long exposure. Most archive interfaces today will only give users access to the individual short exposures and will not reveal the original intention of the initial observing programme.

Automated access to groups of exposures — the so-called Associations — made from stacked observations of the same astronomical object carried out under similar conditions (filters, pointing) and cleaned of cosmic-ray effects allows for a more meaningful delivery of archived data.

In terms of data mining, the Association concept enables automatic analysis, e.g. by classification tools, of the products produced by co-adding individual members of an Association. Catalogues of measurements that will offer a powerful, scientifically oriented user interface to the Archive can be made. Associations are available for HST/WFPC2, HST/ACS and VLT/ISAAC in the form of ‘stacks’.



WFPC2 one-chip single exposure.

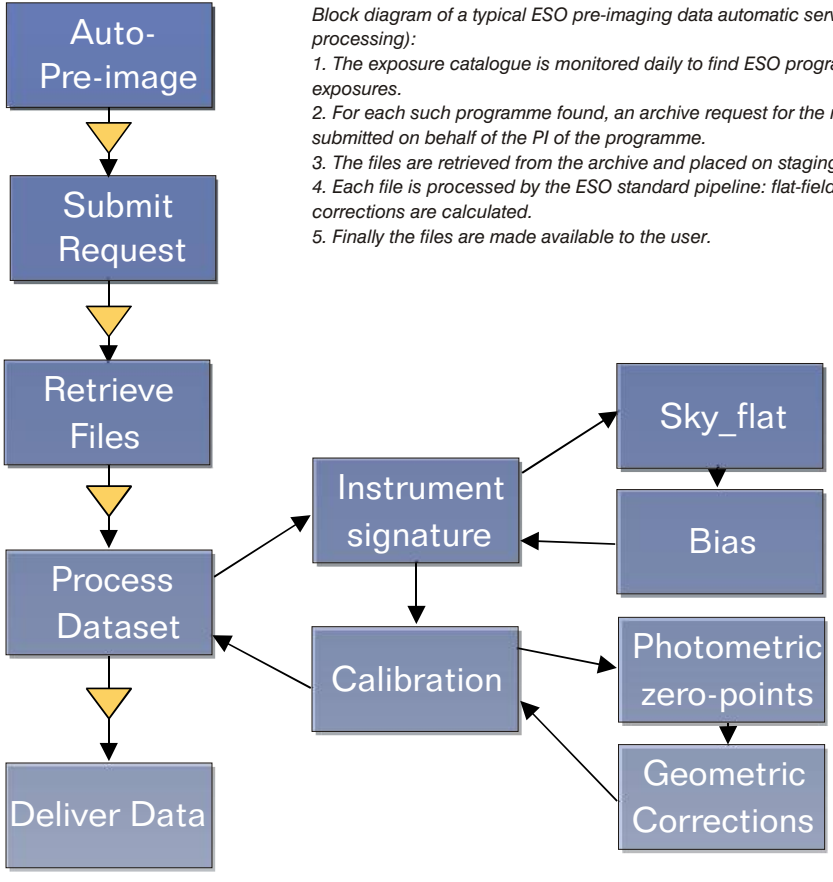


Automatically Associated exposures. This processed exposure is mostly clean of cosmic rays and the Signal-to-Noise ratio is significantly improved.

ON THE FLY CALIBRATION (OTFC)

As time passes, the individual characteristics of a particular instrument are better understood, implying a constant improvement of calibration procedures and reference files. In other words, today's calibration product of last year's observation is quite possibly better than yesterday's calibration of the same observation. This powerful concept is available for all HST instruments and is being implemented for ESO data as well. A first example is the VLT/VIMOS pre-imaging data where Principal Investigators automatically receive their data just hours after the exposures were taken.

The goal of the On-the-Fly Calibration is to provide users with instrumental signature-free products that can immediately be used for analysis by astronomers directly or by tools or packages running on the GRID in VO mode.



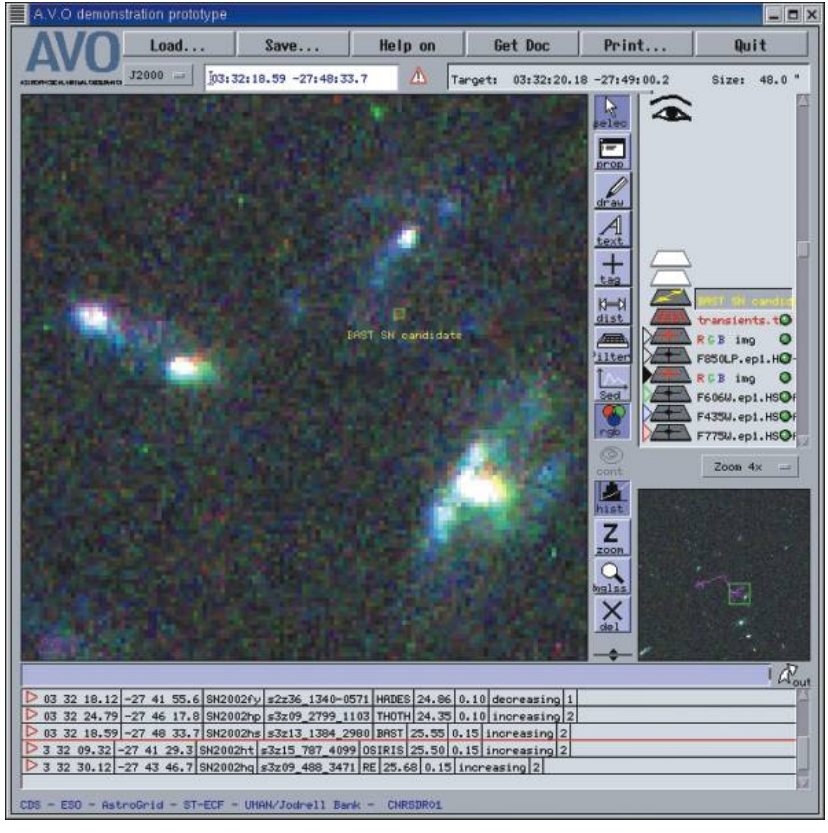
Block diagram of a typical ESO pre-imaging data automatic service (VIMOS pre-imaging On-the-Fly processing):
1. The exposure catalogue is monitored daily to find ESO programmes with new pre-image exposures.
2. For each such programme found, an archive request for the relevant exposures is automatically submitted on behalf of the PI of the programme.
3. The files are retrieved from the archive and placed on staging disks
4. Each file is processed by the ESO standard pipeline: flat-fielding, de-biasing and geometric corrections are calculated.
5. Finally the files are made available to the user.

VIRTUAL OBSERVATORY INITIATIVES

The Archive plays an important role at the heart of the Astrophysical Virtual Observatory (http://www.euro-vo.org): its databases will feed the VO with very high quality data. As on-the-fly calibration removes the instrumental signature, the ESO/ST-ECF data becomes ready for further automatic or assisted data analysis object-extraction, cross-correlation etc. To make the ESO/ST-ECF Archive part of the international VO initiatives, interoperability standards will have to be adopted and therefore our archives are directly involved in the newest initiatives in the area of registries, data modelling, data access protocols etc. within the framework of the International Virtual Observatory Alliance (IVOA, http://www.ivoa.net).

AVO
ASTROPHYSICAL VIRTUAL OBSERVATORY

IVOA



The AVO prototype tool with a selection of GOODS data.

SURVEYS

We offer access to data collected by a number of survey projects carried out within or in collaboration with ESO or the STScI. The sky coverage and the scientific goals of the different surveys cover a broad range from a few square arc-minutes, where the limiting magnitude is maximised (such as the small field of the Hubble Deep Fields), to all-sky surveys with a complete census of all objects in the sky down to a certain magnitude (such as the Digitized Sky Survey). The importance of surveys is easily visible from our access statistics. The DSS survey is by far the most requested of our services.

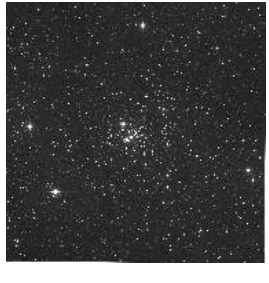
Survey data sets from various projects and collaborations are available from http://archive.eso.org/archive/public_datasets.html. They include:

- Digitized Sky Surveys (DSS): On-line Access to the images from the Digitized Sky Surveys (DSS1, DSS2 red, blue or IR) made available through fast access disks/DVDs (© STScI Digitized Sky Survey, 1993, 1994, AURA, Inc. all rights reserved).
- The HST Hubble Deep Fields
- ESO Imaging Survey (EIS)
- NTT SUSI Deep Field (NDF) and SOFI Infrared Images of the NTT Deep Field
- Science Verification and Commissioning Data from the VLT/I and the Wide Field Imager (WFI)
- HST NICMOS (Near Infrared Camera and Multi-Object Spectrograph) and STIS (Space Telescope Imaging Spectrograph) parallel observations
- ESO Schmidt Plates Collection
- The Great Observatories Origins Deep Survey (GOODS)
- ESO Lauberts and Valentijn Images

Digitized Sky Survey 2 image of the galactic open cluster NGC 869. All three filters (B, R and IR) have here been composited into one colour image.

B

R



IR

CATALOGUES

Catalogues are invaluable resources to assist in preparing observations, cross-correlating with existing Archive data, looking for proper-motion etc. They are well-known references and are accessible through simple web query interfaces. Powerful search engines will return query results very quickly, even for catalogues containing hundreds of millions of entries.

More catalogues are available through the Vizier interface at CDS in Strasbourg (http://vizier.u-strasbg.fr/).

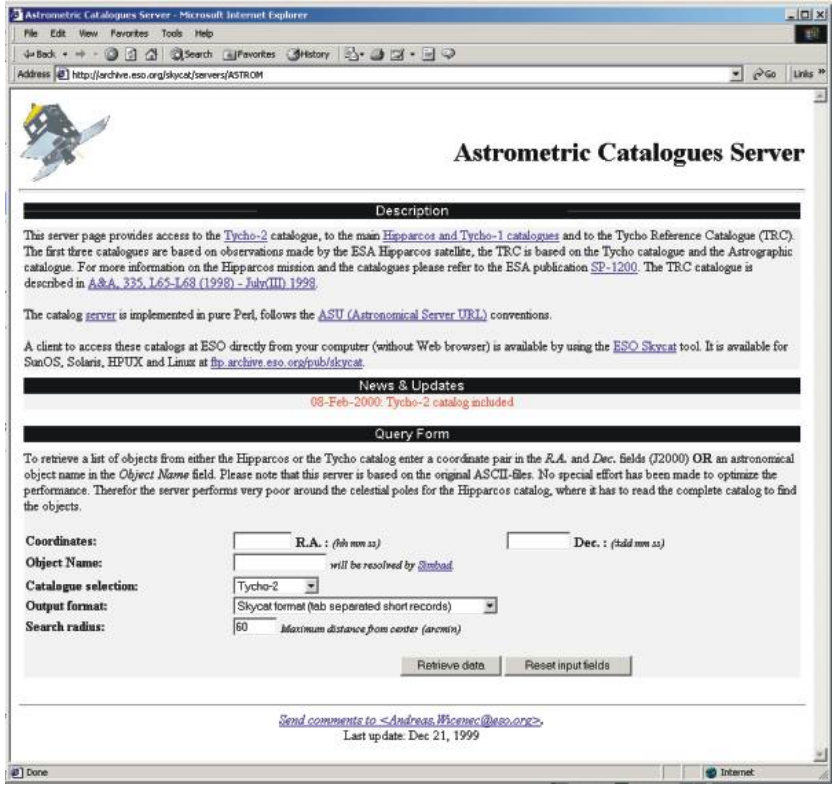
- The GSC1 (Guide Star Catalogue) and GSC-II catalogues.
  Copyright Space Telescope Science Institute.

- The Tycho & Tycho2 catalogue.
  Copyright Copenhagen University Observatory and ESA, 2000.

- The Hipparcos catalogue.
  Copyright ESA, 1997.

- The USNO (US Naval Observatory) A2.0 catalogue.
  Copyright US Naval Observatory, 1998.

- 2MASS.
  Copyright: UMass, IPAC (JPL/ Caltech), NASA and NSF.

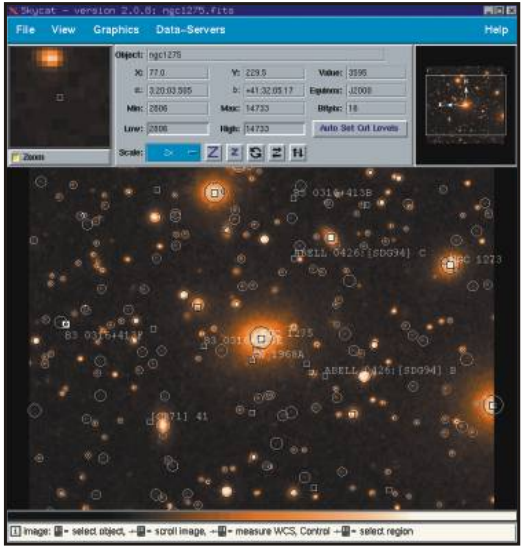


This is the query page for the astrometric/photometric reference catalogues Tycho-2, Hipparcos, Tycho-1 and the Tycho Reference Catalogue (TRC). The possible query parameters are kept to a minimum to support a cone search here.

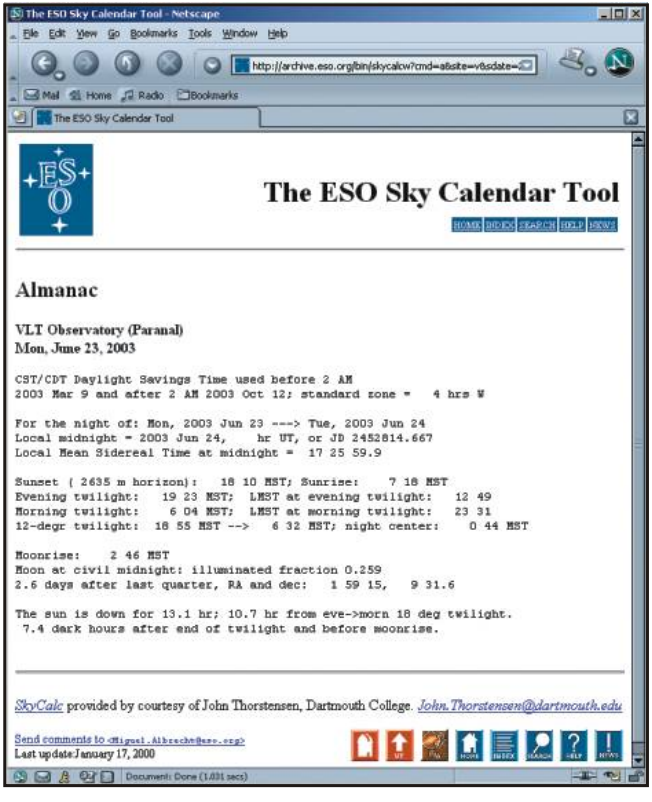
SOFTWARE TOOLS

Most of the data stored in the Archive are digital data requiring software to analyse or even look at them. Some of the tools that have been developed for the operation of the observatories or the Archive are useful for a wider public and are thus available through our web-site. This includes sophisticated astronomical tools such as Skycat or JSkycat, observation preparation tools and also smaller hands-on tools like FTU (Fits Translation Utility), that help to solve problems with the data formats or descriptions.

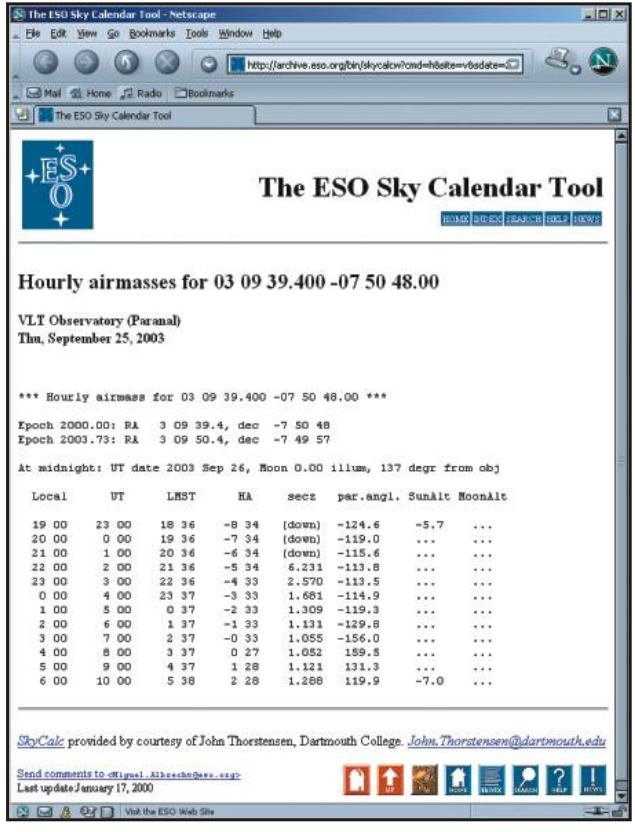
- Handling and visualisation of astronomical data with SkyCat JIPA, DSS batch, Jsky and ESO catalogue server software
- Preparation of observations: Night Sky Almanac, Object Observability, Hourly Airmasses
- Access to the ESO data dictionaries, glossaries and list of acronyms commonly used at ESO
- FITS tools



Skycat is a widely used image display and catalogue cross-correlation tool that can overlay catalogues on FITS-images. It is very versatile and allows the user to connect remotely to full archives, collections of catalogue and image servers.



Example of the almanac output of the Sky Calendar tool calculated for 23 June 2003 for the Paranal observatory.



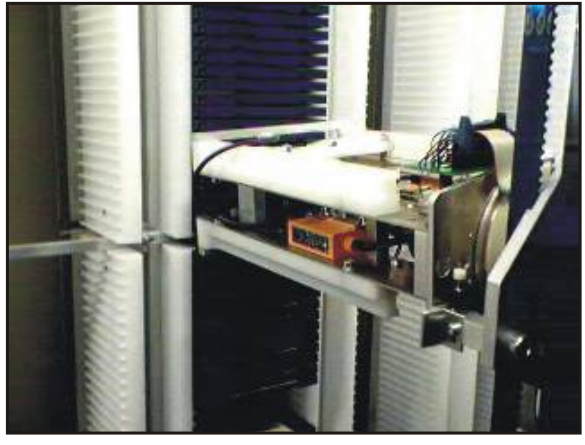
This screen-shot shows the hourly airmass table for the object NGC1234 calculated for Sep. 25th 2003 for the Paranal Observatory.

TECHNOLOGY

To deal with an exponentially increasing data input AND output volume, the ESO/ST-ECF Archive has to remain at the forefront of technology. For example, the data storage technology has changed every three years on average. Since 1994, the Web has constituted the main vehicle for providing services. ESO was among the first to invest in web-based technologies to browse relational databases. The entire data flow concept is centred on a relational database management system. Today ESO is at the forefront of exploring and exploiting new technologies like XML, Java and data warehouses. Many challenges await us in the next few years: new high-volume telescope/instruments will come on-line and will need to have their data archived: VST/OmegaCAM, VISTA, ALMA. UKIDSS survey data will also be available from the Archive. This will require data storage and distribution paradigm changes, with virtual observatory approaches to access and work with astronomical data.

The Next Generation Archive Systems Technologies (NGAST, http://archive.eso.org/NGAST) is now in operation. It offers low cost, high capacity storage and large processing power at the same time. This makes it the system of choice for VO and GRID computing needs.

The favoured Next Generation Archive Systems Technology is currently based on magnetic disks.



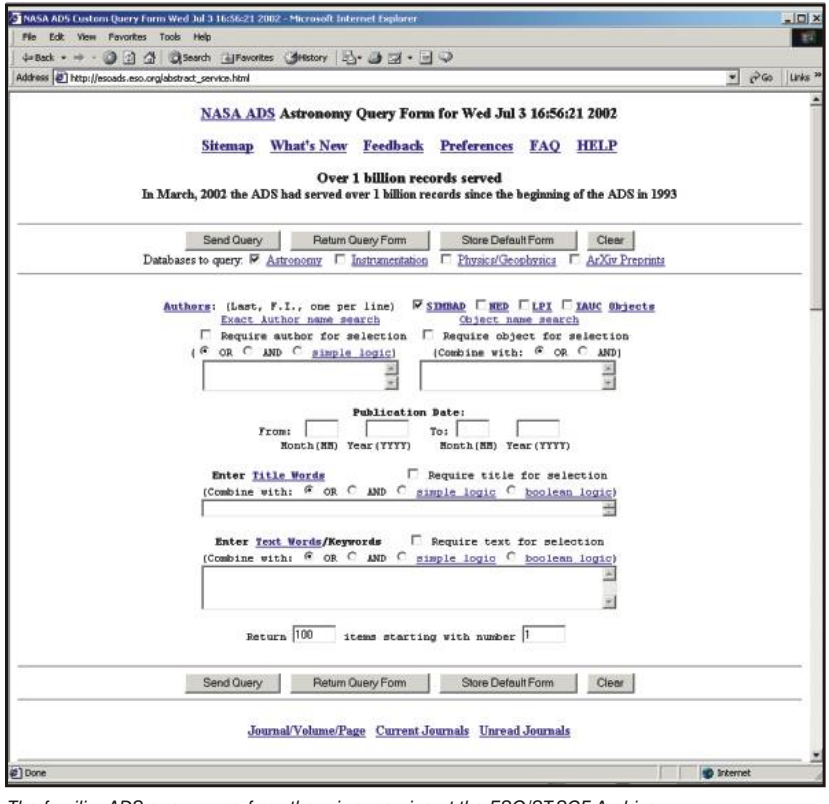
A close-up of the Archive DVD robot.

PUBLICATIONS ACCESS

Reading scientific papers and publications is essential for all astronomers. The way this is done today is very different from what it was ten years ago. The advent of the World Wide Web has revolutionised information search and navigation through documents. Astronomy has pioneered the field of bibliographic searches by making a very large fraction of all scientific papers ever published in the field available on-line and fully indexed. One of the major contributors has been the ADS (NASA Astrophysics Data System). Our Archive took advantage of ADS services early on and offered cross-correlation of proposal abstracts and titles with ADS indexed papers transparently. Now the reverse operation is also possible, whereby results of ADS searches are seamlessly linked to the relevant observations in our Archive. One mouse click is all it takes to go from paper to observations and vice-versa.

Services
The ADS mirror service: abstracts of all major astronomical journals (http://esoads.eso.org/). Provided by NASA's Astrophysics Data System Bibliographic Services

- The ESO library with publications from the ESO User's community
- HST publications abstract
- Cross-references from all HST observations to published papers that use the data..



The familiar ADS query page from the mirror service at the ESO/ST-SCF Archive.

Register as an Archive user at:
http://archive.eso.org/register/new

GLOSSARY

ACS	Advanced Camera for Surveys
ADS	Astrophysics Data System
AVO	Astrophysical Virtual Observatory
CADC	Canadian Astronomical Data Centre
CDS	Centre de Donn es de Strasbourg
DLT	Digital Linear Tape
DMD	Data Management Division
DSS-2	Digital Sky Survey (2nd verson)
DVD	Digital Versatile Disk
DVD-R	Digital Versatile Disk - Recordable
EIS	ESO Imaging Survey
EMMI	ESO Multi Mode Instrument
ESA	European Space Agency
ESO	European Southern Observatory
FITS	Flexible Image Transport System
FTU	FITS Translation Utility
FOS	Faint Object Spectrograph
GB	Giga-byte
GHRS	Goddard High Resolution Spectrograph
GSC-II	Guide Star Catalogue, version 2.0
GUI	Graphical User Interface
HST	Hubble Space Telescope
HTML	Hyper Text Markup Language
IFS	Integral Field Spectroscopy
ISAAC	Infrared Spectrometer and Array Instrument
JIPA	Java Image Preview Applet
MOS	Multi-Object Spectroscopy
NGAS	Next Generation Archive System
NICMOS	Near Infrared Camera, Multiple Object Spectrograph
NTT	New Technology Telescope
OTFC	On-The-Fly Calibration
OTS	Operations Technical Support
PI	Principal Investigator
SQL	Structured Query Language
STIS	Space Telescope Imaging Spectrograph
ST-ECF	Space Telescope - European Coordinating Facility
STScI	Space Telescope Science Institute
TB	Tera byte
TRC	Tycho Reference Catalogue VIMOS VIsible Multi-Object Spectrograph
VINCI	VLT INterferometer Commissioning Instrument
VO	Virtual Observatory
VLT	Very Large Telescope
WFI	Wide-Field Imager on the ESO 2.2m telescope
WFPC2	Wide Field and Planetary Camera 2


The ESO/ST-ECF Science Archive Facility is a joint collaboration of the European Southern Observatory (ESO) and the Space Telescope-European Coordinating Facility (ST-ECF)
http://archive.eso.org