

LINUX ASTRONOMICAL SOFTWARE

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Abstract. Most popular astronomical software for scientiest and non professional astronomers based on LINUX operational system are reviewed. The software packages are grouped in 10 directions - *Data Analysis Packages, GRID software, Modeling and Simulations, Organizers, Planetariums software, Radio & Interferometry software, Spectrum Analysis, Visualization, VO software and X_ray analysis software.* Included are data reduction packages as IRAF, MIDAS and SExtractor, simulation and modeling software – e.g. GADGET, GALFIT and SYNSPEC, organisers – e.g. FITS_viewres, SKYCAL and WCS_tools, planetarium software – e.g. CELESTIA, KSTARS and XEPHEM, analysis of radio and interferometric data as AIPS, MIRIAD and SPEX_tool, spectral analysis software – e.g. SPECTRUM and SPECVIEW, visualisation software – e.g. ALADIN, DS9, QFITSview and ESO's SKYCAT and VIRGO, and analysis of X_ray data – e.g. CIAO, SAS and XSPEC. Specialised GRID and VIRTUAL OBSERVATORY software are brifly presented here and in details in Petrov, Dechev and Atanasov paper in this volume. More than 100 LINUX software products are presented.

1. INTRODUCTION

Fast developing of the astronomical science, new telescopes and equipments and tremendous quantity of astronomical data enforce the astronomers very often to know and use a lot of different, some times quite specialized or sophisticated astronomical software. Sometimes it is not so easy to decide which package will give you the best solution for the task you are interested in. There are a lot of free specialized astronomical software as some commercial packages (e.g. IDL) too. Here we presented ca. 110 free astronomical software packages for LINUX – the free operational system. Distributed in 10 groups - Data Analysis Packages, GRID software, Modeling and Simulations, Organizers, Planetariums software, Radio & Interferometry software, Spectrum Analysis, Visualization, VO software and X_ray analysis software, all the packages are reviewed and presented in alphabetical order in each group. Sometimes a platform independent packages - Java application are presented. In any case detailed instruction for software installation and user guides could be found in the official WEB_pages of the authors or distributors (see references here).

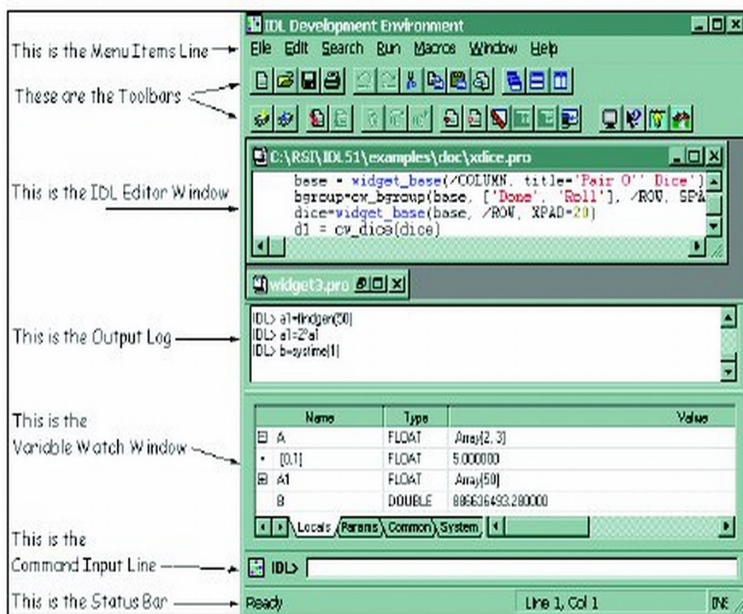
GRID and VO software is briefly mentioned here, as the full description of these special packages are presented in Petrov et al. (2012) in this volume. In the Sections 2 to 11 all the reviewed packages are presented. All the figures are snapshots from the WEB_pages or real execution of the software packages.

2. DATA ANALYSIS PACKAGE

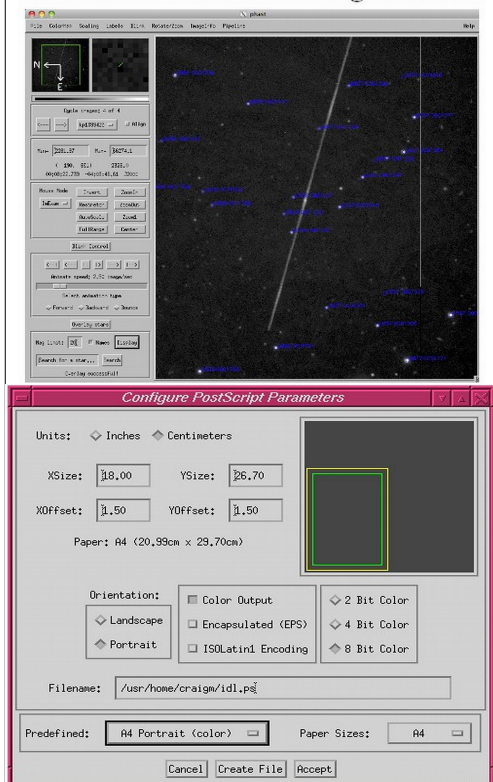
2.1 CCDPROC (<http://www.astronomy.ohio-state.edu/~pogge/Software/>) - *performs basic reductions on raw CCD images* (overscan bias subtraction, trim, zero and/or dark subtraction, and flat fielding), creating a reduced image ready for subsequent analysis. A process control (proc) file contains the instructions for performing the reduction. **Ccdproc** is designed to be used *for fast pipeline reductions of CCD images*, but requires that the necessary zero (2D Bias) and normalized flat-field images be already prepared using standard image reduction packages like IRAF, VISTA, IDL, etc. Author R. Pogge.

2.2 FIGARO (<http://www.aao.gov.au/figaro/>) - a data reduction system that originated at Caltech at the Anglo-Australian Observatory. Although it is intended to be able to deal with any sort of data, almost all its applications to date are geared towards *processing optical and infra-red data...* (by Keith Shortridge).

2.3 IDL (Registered trademark of ITT Corporation) - *Data Analysis/Visualisation package*. The IDL Astronomy Users Library is a central repository for low-level astronomy software written in the commercial language **IDL**. The Library is a collection of procedures from which users can pick and choose for their own use. **Figure 1a,b,c**. Snapshots of some applications.



PhAst: A flexible IDL image tool



2.4 IRAF (<http://iraf.noao.edu/iraf-ftp.html>) - an *Image Reduction and Analysis Facility*, a general purpose software system for the reduction and analysis of astronomical data. **Figure 2**. Snapshot of IRAF home page.

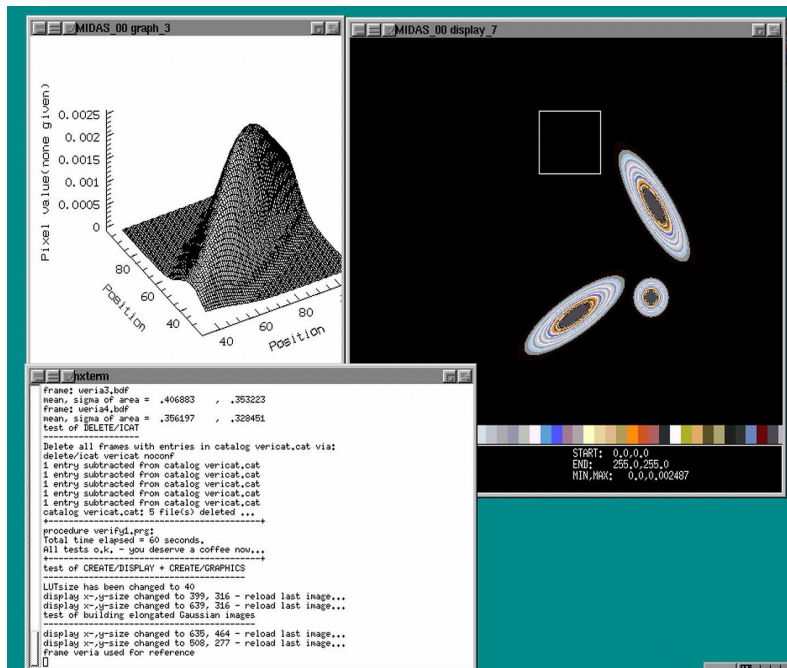


2.5 ISIS (<http://asterisk.apod.com>) - ISIS is a complete package to process CCD images using the image Optimal subtraction method (Alard & Lupton 1998, Alard 1999). ISIS includes a number of facilities to compute the light curves of variables objects from the subtracted images. **Figure 3.** Snapshot of ISIS logo.



2.6 MIDAS

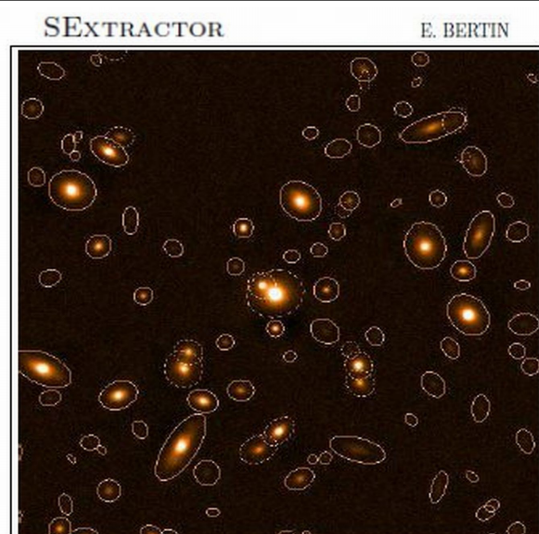
(<http://www.eso.org/sci/software/eso/midas/>) - the acronym for the Munich Image Data Analysis System which is developed and maintained by the European Southern Observatory. The official name, **ESO-MIDAS**, is a registered trademark. The ESO-MIDAS system provides general tools for image processing and data reduction with emphasis on astronomical applications including imaging and special reduction packages for ESO instrumentation at La Silla. In addition it contains applications packages for stellar and surface photometry, image sharpening and decomposition, statistics and various others (Grosbol & Ponz 1990). **Figure 4.** Snapshot of MIDAS work area.



2.7 SEXTRACTOR

(<http://www.astromatic.net/software/sextractor>) - a program that builds a catalog of objects from an astronomical image. Although it is particularly oriented towards reduction of large scale galaxy-survey data, it can perform reasonably well on moderately crowded star fields. A "teaching" program for object selection is EYE (Bertin & Arnouts 1996). *Rem.: In the site* <http://www.astromatic.net/software/> one could find and other programs from E.Bertin...

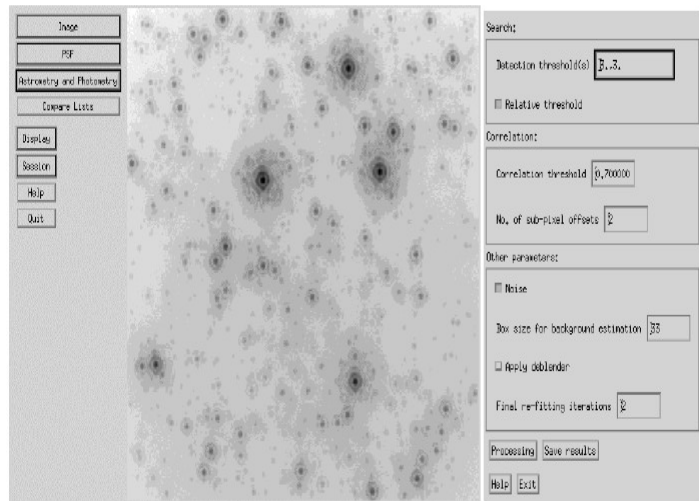
Figure 5. Snapshot of SExtractor logo.



2.8 STARFINDER.IDL

(<http://asterisk.apod.com/>) - an *code for the deep analysis of stellar fields*, designed for Adaptive Optics well-sampled images. The *Point Spread Function is extracted directly from the frame*, to take into account the actual structure of the instrumental response and the atmospheric effects. The code is written in IDL language and organized in the form of a self-contained widget-based application, provided with a series of tools for data visualization and analysis (Diolaiti et al. 2000).

Figure 6. Snapshot of STARFINDER application.



2.9 STARLINK (<http://starlink.jach.hawaii.edu/starlink>) - A full set of data reduction and analysis tools. The Starlink Project was a long running UK Project supporting astronomical data processing. It was shut down in 2005 but the software continues to be developed at the Joint Astronomy Centre and is open source (Disney et al. 1982). See a Starlink – brochure (1996) too.

2.10 STSDAS (http://www.stsci.edu/institute/software_hardware/stsdas) - The Space Telescope Science Data Analysis System (STSDAS) is a software package for reducing and analyzing astronomical data. It is layered on top of IRAF and provides general-purpose tools for astronomical data analysis as well as routines specifically designed for HST data. The TABLES package sits alongside STSDAS and provides tools and libraries for working with tabular data. STSDAS requires TABLES, but one may use TABLES without STSDAS.

2.11 VISTA - There are two different versions, distributed as *xvista*:

- Xvista version 7.xx (<http://ganymede.nmsu.edu/holtz/xvista/>) maintained and distributed by **Jon Holtzman** at the New Mexico State University, is an image processing program designed to be used primarily with astronomical data. It contains routines *for reading, displaying, basic image processing, and specialized tasks for the analysis of astronomical imaging and spectroscopic data*.
- **Richmond & Treffers's** XVista, (ver. 0.1.9/2010) is a suite of programs *for analyzing and displaying astronomical images* on computers running Unix-like operating systems and X Windows (Richmond et al. 1993, 1995).

3. GRID SOFTWARE - details presented during the VII_SBAC (Petrov et al. 2012)

3.1 AMEEPAR (<http://www.jpl.nasa.gov/>) - parallel processing for hyperspectral imaging (Plaza et al., 2006).

3.2 CACTUS (<http://www.cactuscode.org>) - toolkit to numerically simulate extremely massive bodies, such as neutron stars and black holes.

3.3 GADGET-2 (<http://www.mpa-garching.mpg.de/gadget/>) – a freely available code for cosmological N-body/SPH simulations

3.4 COSMIC SIMULATION (<http://www.mpa-garching.mpg.de/galform/millennium/>) - A virtual universe – GIMIC and Millennium simulations

3.5 CLUSTERFINDER (<http://www.gac-grid.de/project-products/Applications/ClusterFinder.html>)

3.6 CRBLASTER (<http://www.noao.edu/staff/mighell/crblaster>) - a fast parallel-processing program for cosmic ray rejection (Mighell 2010)

3.7 Einstein@home (<http://boinc.berkeley.edu/wiki/Einstein@Home>)

3.8 Milkyway@home (<http://milkyway.cs.rpi.edu/milkyway/>)

3.9 Nbody6++ (<http://www.ast.cam.ac.uk/~sverre/web/pages/nbody.htm>) - direct N-body integrator used for simulations of dense star clusters, galactic nuclei, and problems of star formation (Aarseth 2001).

3.10 N_body-sh1p (http://modesta.science.uva.nl/Software/src/nbody_sh1p.tar.gz) - a parallel direct N_body code - *an educational N-body integrator* (Konecny & Fürst 2007). (see 4.9 too...).

3.11 SETI@home (<http://setiathome.berkeley.edu/>) - SETI (Search for Extraterrestrial Intelligence) - to detect intelligent life.

3.12 SKYMAKER (<http://www.astromatic.net/software/skymaker>) - a program that simulates astronomical images (Bertin 2009).

3.13 SYNTSPEC (<http://www.balticgrid.org/>) - The Synthetic spectra modeling under GRIDCOM interface (Mikolaitis & Tautvaisiene 2009).

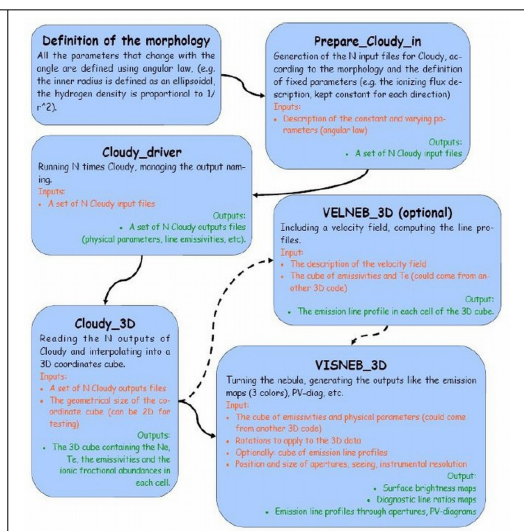
3.14 VIRGO (<http://virgo.org.ua/>)

4. MODELLING & SIMULATIONS

4.1 CHANGA – (<http://www-hpcc.astro.washington.edu/tools/changa.html>) - (**Charm N-body GrAvity** solver) is a code to perform collisionless N-body simulations. It can perform cosmological simulations with periodic boundary conditions in comoving coordinates or simulations of isolated stellar systems. It also can include hydrodynamics using the Smooth Particle Hydrodynamics (SPH) technique. It uses a Barnes-Hut tree to calculate gravity, with hexadecapole expansion of nodes and Ewald summation for periodic forces. Timestepping is done with a leapfrog integrator with individual timesteps for each particle.

4.2 CHIANTI (<http://www.chiantidatabase.org/chianti.html>) - An Atomic Database for Spectroscopic Diagnostics of Astrophysical Plasmas.

4.3 CLOUDY.IDL (<http://www.nublado.org/>; <http://sites.google.com/site/cloudy3d/> - author Christophe Morisset, 2010) - designed to *simulate emission line regions ranging from the intergalactic medium to the Broad Line Regions of Quasars*. ... Dilute gas is heated and ionized by the radiation field of a central object. Under these circumstances *it is possible to predict the physical conditions* (e.g. the run of ionization, density, and temperature) *of the gas, and its resulting emission-line spectrum*, in a unique and self-consistent manner. For this the equations of statistical and thermal equilibrium, equations which balance ionization-neutralization processes, and heating-cooling processes are used. **Figure 7.** Snapshot of CLOUDY flowchart.

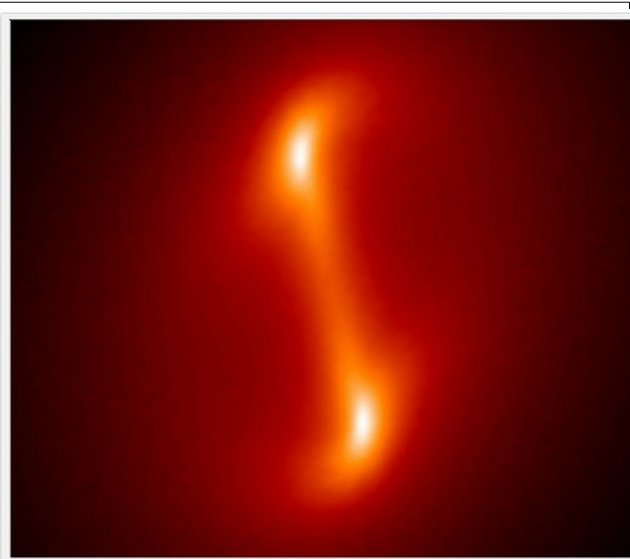


4.4 COSMICS (<http://asterisk.apod.com/>) - a package of FORTRAN programs useful for *computing transfer functions and microwave background anisotropy for cosmological models*, and for generating gaussian random initial conditions for nonlinear structure formation simulations of such models. Four programs are provided: (1) *linger_con* and *linger_syn* integrate the linearized equations of general relativity; (2) *matter*, and radiation in conformal Newtonian and synchronous gauge, respectively; (3) *deltat* integrates the photon transfer functions computed by the *linger* codes to produce photon anisotropy power spectra; (4) *graphic* tabulates normalized matter power spectra and produces constrained or unconstrained samples of the matter density field (Ma & Bertschinger 1995) .

4.5 FASTELL (<http://asterisk.apod.com/>) - a code *to calculate quickly and accurately the lensing deflection and magnification matrix* for the softened power-law elliptical mass distribution (SPEMD) lens galaxy model. The *SPEMD consists of* a softened power-law radial distribution with elliptical isodensity contours. Because of their simplicity, axisymmetric mass distributions are often used to model gravitational lenses. Since galaxies are usually observed to have elliptical light distributions, mass distributions with elliptical density contours offer more general and realistic lens models (Barkana 1998).

4.6 GADGET (<http://www.mpa-garching.mpg.de/gadget/>) - a freely available code for *cosmological N-body/SPH simulations* on massively parallel computers with distributed memory. The code can be run on essentially all supercomputer systems presently in use, including clusters of workstations or individual PCs. *GADGET computes gravitational forces with a hierarchical tree. It follows the evolution of a self-gravitating collisionless N-body system, and allows gas dynamics to be optionally included.* Author - Prof. Dr. Volker Springel and later on Naoki Yoshida.

Figure 8. Snapshot from GADGET-2 working area.



4.7 GALACTICUS (<http://sites.google.com/site/galacticusmodel/downloads>) – a project, led by Andrew Benson, aims to *build a comprehensive model of galaxy formation*. Galacticus is *designed to solve the physics involved in the formation of galaxies within the current standard cosmological framework*. It is of a type of model known as "semi-analytic" in which the numerous complex non-linear physics involved are solved using a combination of analytic approximations and empirical calibrations from more detailed, numerical solutions. Models of this type aim to begin with the initial state of the Universe (specified shortly after the Big Bang) and apply physical principles to determine the properties of galaxies in the Universe at later times, including the present day. *Typical properties computed include the mass of stars and gas in each galaxy, broad structural properties (e.g. radii, rotation speeds, geometrical shape etc.), dark matter and black hole contents, and observable quantities such as luminosities, chemical composition, etc.*

4.8 GALFIT (<http://users.obs.carnegiescience.edu/peng/work/galfit/galfit.html>) - **A two-dimensional (2-D) fitting algorithm designed to extract structural components from galaxy images, with emphasis on closely modelling light profiles of spatially well-resolved, nearby galaxies observed with the Hubble Space Telescope.** 2-D models such as the "Nuker" law, the Sersic (de Vaucouleurs) profile, an exponential disk, and Gaussian or Moffat functions are used. The azimuthal shapes are generalized ellipses that can fit disky and boxy components. Many galaxies with complex isophotes, ellipticity changes, and position-angle twists can be modeled accurately in 2-D. *This is illustrated by way of seven case studies*, which include regular and barred spiral galaxies, highly disky lenticular galaxies, and elliptical galaxies displaying various

levels of complexities. Author C. Y. Peng.

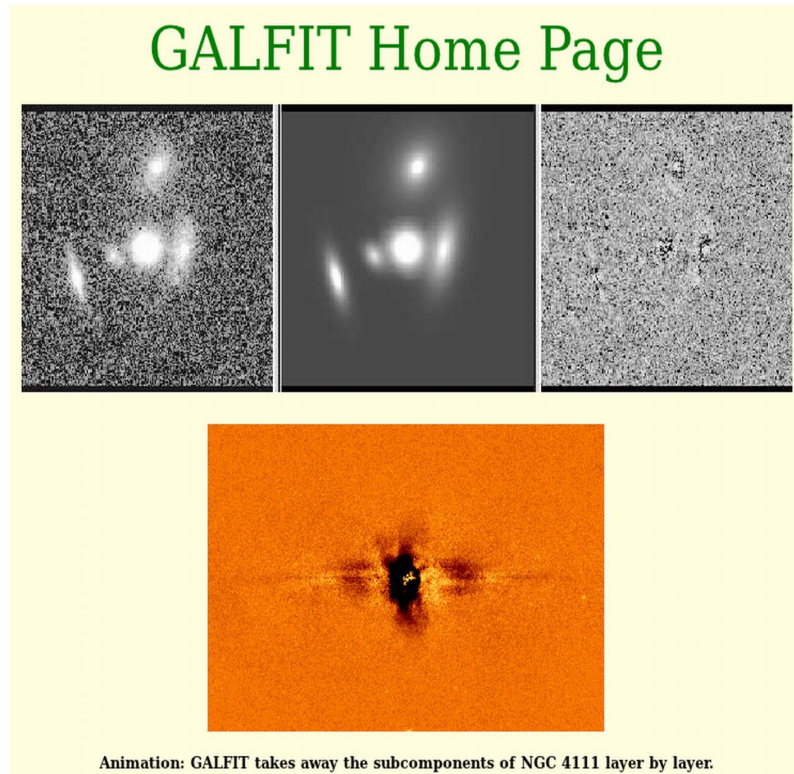
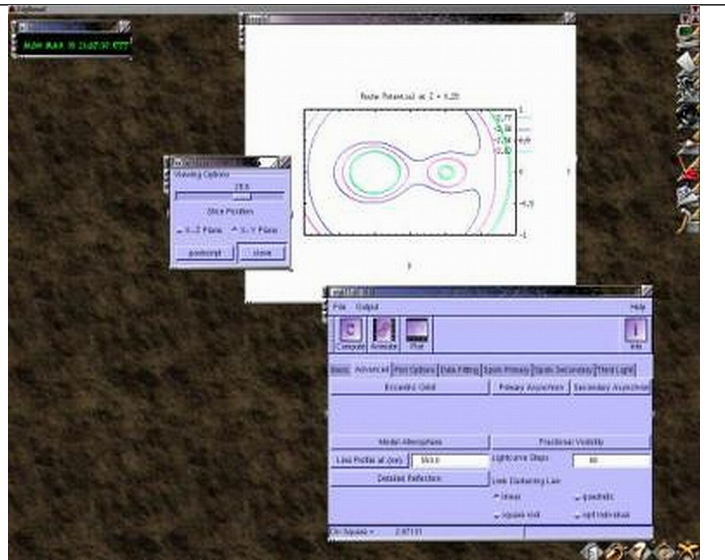


Figure 9. Snapshot from GALFIT working area.

4.9 N-BODY simulations ([http://www.scholarpedia.org/article/N-body_simulations_\(gravitational\)](http://www.scholarpedia.org/article/N-body_simulations_(gravitational))) - `nbody_sh1p` - *a parallel direct N-body code. Educational N-body integrator* with a shared but variable time step (the same for all particles but changing in time), using the Hermite integration scheme (Konecny & Fürst 2007). Typical command line (generates `n24body.out`) : `*** nbody_sh1p < n24body.in > n24body.out`

4.10 NIGHTFALL (<http://www.la-samhna.de/nightfall/nightfall-1.70.tar.gz>) - ... “astronomy application for fun, education, and science. It can produce animated views of eclipsing binary stars, calculate synthetic light curves and radial velocity curves, and eventually determine the best-fit model for a given set of observational data of an eclipsing binary star system. Nightfall comes with a user guide, and a set of observational data for several eclipsing binary star systems”. (Mahy et al. 2011). **Figure 10.** Snapshot from NIGHTFALL working area.



4.11 PANDORA (<https://www.cfa.harvard.edu/~avrett/pandora.html>) - Pandora is a *general-purpose non-LTE computer program for calculating stellar atmosphere models and detailed line and continuum spectra*. Recent applications include extensive modeling of the outer atmosphere of the Sun and other late-

type stars, including effects of mass flows; the atmospheric response to external ionizing radiation; and the effects of ion diffusion (Averet & Loeser 2003) .

4.12 SYNSPEC (<http://nova.astro.umd.edu/Synspec43/>) - is a *general spectrum synthesis program*. It assumes an existing model atmosphere, calculated previously with *TLUSTY* or taken from the literature, for instance from the Kurucz grid of models. The opacity sources (continua, atomic and molecular lines) are fully specified by the user. An arbitrary stellar rotation and instrumental profile can be applied to the synthetic spectrum. *Synplot* is a user-friendly IDL wrapper around Synspec. Synplot is keyword-driven and incorporates all the necessary plotting resources for spectral analysis (see 3.12 *TLUSTY*). Authors – Ivan Hubeny & Thierry Lanz.

4.13 TIPSY (<ftp://ftp-hpcc.astro.washington.edu/pub/hpcc/tipsy-XX.tar.gz/>; <http://astro.washington.edu/index.html>) - the **Theoretical Image Processing System**. *Display and analyze the results of N-body simulations*. *TIPSY* is a special package built to could *easily perform the following functions*: Display particle positions (as points), and velocities (as line segments) from an arbitrary viewpoint; Zoom in to a chosen position. Due to their extremely clustered nature, structure of interest in an N-body simulation is often so small that it can not be seen when looking at the simulation as a whole; Color particles to display scalar fields. Examples of such fields are potential energy, or for SPH particles, density and temperature; Selection of a subset of the particles for display and analysis; Following selected particles from one timestep to another; Finding cumulative properties of a collection of particles. This usually involves just a sum over the particles. *The basic data structure is an array of particle structures*. Since *TIPSY* was built for use with cosmological N-body simulations, there are actually *three separate arrays for each of the types of particle used in such simulations: collisionless particles, SPH particles, and star particles*.

4.14 TLUSTY (<http://nova.astro.umd.edu/>) - The present set of computer programs is *a package designed to accomplish a wide range of spectroscopic diagnostics*. In its maximum configuration, the user may start from scratch and calculate a model atmosphere of a chosen degree of complexity, and end with a synthetic spectrum in a wavelength region of interest for an arbitrary stellar rotation and an arbitrary instrumental profile. The user may also model the vertical structure of annuli of an accretion disk. Authors – Ivan Hubeny & Thierry Lanz.

5. ORGANIZERS

5.1 APT - The Astronomer's Proposal Tool (<http://www.stsci.edu/hst/>). Write, validate and submit proposals for the Hubble Space Telescope.

5.2 CONSKY (<http://asterisk.apod.com>) - This program addresses the question of *what resources are needed to produce a continuous data record of the entire sky down to a given limiting visual magnitude*. The program simulates a small camera/telescope or group of small camera/telescopes collecting light from a large portion of the sky. From a given stellar density derived from a Bahcall - Soneira Galaxy model, the program first converts star densities at visual magnitudes between 5 and 20 to number of sky pixels needed to monitor each star simultaneously. From pixels, *the program converts input CCD parameters to needed telescope attributes, needed data storage space, and the length of time needed to accumulate data of photometric quality for stars of each limiting visual magnitude over the whole sky*. The program steps through photometric integrations one second at a time and includes the contribution from a bright background, read noise, dark current, and atmospheric absorption (Nemiroff, Robert J.; Rafert, J. Bruce: 1999, PASP, Volume 111, Issue 761, pp. 886-897.).

5.3 FITS viewers. **Figure 11.** Snapshot of FITS viewers and converters page.



FITS Image Viewers and Format Converters

FITS Image Viewers

- [SAOImage ds9](#) - astronomical visualization application from SAO
- [fv](#) - FITS file viewer and editor (supports FITS images and FITS tables)
- [FITSview](#) - FITS image viewer from NRAO
- [SkyCat](#) - ESO tool combines image visualization and access to catalogs
- [GAIA](#) - an image display and analysis tool from the U.K. Starlink Project. It is a derivative of the ESO SkyCat tool
- [Aladin](#) - Interactive Sky Atlas
- [APLpy](#) - Astronomical Plotting Library in Python is a Python module aimed at producing publication-quality plots of astronomical imaging data in FITS format.
- [giv](#) - A cross platform (posix and Windows) image viewer designed especially for scientific vision and computational geometry. Supports interactive brightness and contrast adjustment of 2D images and 3D cubes in various data formats, including FITS. Also supports drawing vector graphics on top of the image.
- [PhAst](#) - A flexible IDL tool to display and analyze FITS images. It can calibrate raw images, provide astrometric solutions, and do circular aperture photometry. PhAst allows the user to load, process, and blink any number of images. Requires either an IDL license, or installation of the (free) IDL Virtual Machine.
- [QFitsView](#) - An image viewer for 1-D, 2-D, and 3_D FITS images. It is written in C++ and uses the Qt widget library. Binary executables for Microsoft Windows, Linux, and Mac OSX, as well as the source code, are available.
- [Libvips](#) - a fully demand-driven, threaded image processing library with no image size limits and with good support for colour. Reads and writes FITS images, as well as TIFF, JPEG, PPM, PNG, and other file formats. Has interfaces to C, C++ and Python, and a command-line interface that can be called from shell scripts.

Image Format Converters - FITS to/from GIF, JPEG, etc

- [Netpbm](#) - a package of graphics programs and programming library. The [documentation](#) is on-line. In particular, see the [fistopnm](#) and [pnmtofits](#) programs. To first order, the following command converts a jpeg image to a FITS image on most Linux systems:


```
djpeg file.jpg | pnmtofits > file.fits
```

 where "djpeg" is available in the libjpeg RPM package.
- [ImageMagick](#) - read, write, and manipulate images in over 68 formats
- [pbmplus](#) - image file format conversion package
- [gimp](#) - GNU Image Manipulation Package
- [FITS2jpeg](#) - a FITS to jpeg converter provided by Bill Cotton (NRAO). It needs the CFITSIO and libjpeg libraries and produces grayscale images.
- [SAOImage ds9](#) - this FITS visualization application from SAO allows the image to be saved as a jpeg, tiff, png, or ppm file on disk (use File->Save)
- [MicroObservatory Image 2.0](#) - Image display and processing program can perform FITS to GIF conversion and create RGB color images or animated GIF files.
- [fts2gif](#) - a simple FITS to gif converter written by Michal Szymanski (Warsaw University Observatory). It requires the "raw2gif" application from the giflib-3.0 library (Linux and Solaris versions of raw2gif are included in the fts2gif tar file).

5.3.1 STIFF

(<http://www.astromatic.net/2010/02/10/stiff-2-1-release>) is a program that *converts scientific FITS images to the more popular TIFF format* for illustration purposes. Last version – 2.1 was included in ALADIN. Author E. Bertin.

Figure 12. Comparisson of two types of color image creators.



The same 3 R,G and B deep-sky images processed by FITS LIBERATOR (left) and STIFF (right), using the same intensity cuts.

5.4 GASGANO (<http://www.eso.org/sci/software/gasgano/>) - a data file organizer by ESO “to manage and organize in a systematic way the astronomical data observed and produced by all VLT compliant telescopes”.

5.5 HERA (<http://heasarc.nasa.gov/hera/>) - The Hera data processing facility provides *many general utility programs for manipulating FITS format images and tables*. These general tools are organized into *several different FTOOLS packages*:

- ✧ **HEATTOOLS** - tasks for listing, editing and calculating statistics about any FITS file, image processing calculators, and general table manipulation tools (sorting, appending, selecting rows, etc.)
- ✧ **FIMAGE** - utilities for general image processing and manipulation.
- ✧ **FUTILS** - a large set of general FITS utility program mainly for manipulating FITS headers or tables; some of these are older versions of tools in the HEATTOOLS package.

Hera also provides hundreds of more specialized programs, mainly for professional researchers, to analyze data from high-energy astrophysics missions such as ROSAT, Chandra, XMM-Newton, Swift, and Suzaku. Currently, these tools include all the hundreds of programs in the HEASARC FTOOLS and the Chandra CIAO data analysis packages, as well as several of the most frequently used programs in the XMM-Newton SAS package.

5.6 SKYCAL

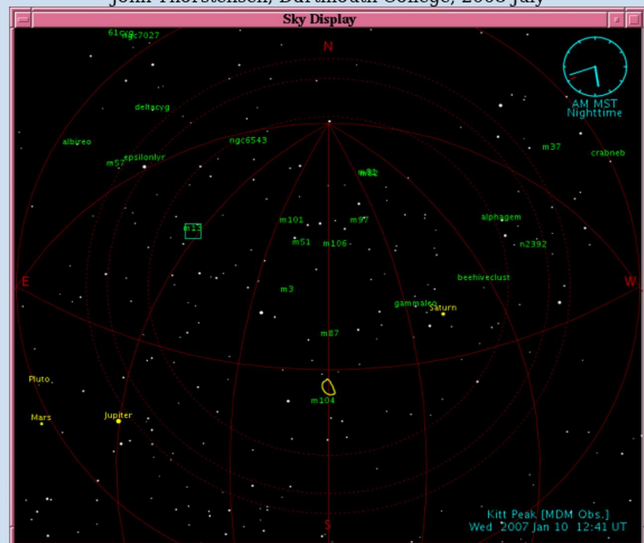
(<http://www.dartmouth.edu/~physics/faculty/skycalc/JSkyCalc.jnlp> and

http://www.briancasey.org/artifacts/astro/skycalendar_notes.html) – *in fact a two different programs: Skycalc is an interactive tool*

which conveniently handles the time-and-the-sky calculations commonly encountered in optical astronomy. It has many features useful for planning observations at the telescope. Ver.6 and newer have a GUI interface too. The picture shows JAVA version of the SkyCalc. Skycalendar prints a table of sunrise, sunset, moonrise, moonset, and so on, organized on a nightly (double-dated) basis for any site. Author - John Thorstensen with a Web interface by Brian Casey. Figure 13. Snapshot of Java applet of SkyCalc.









JSkyCalc -- A Convenient, Portable Observing Aid

John Thorstensen, Dartmouth College; 2008 July



5.7 WCSTOOLS (<http://tdc-www.harvard.edu/software/wcstools/wcstools.wcs.html>) - a package of programs and a library of utility subroutines for *setting and using the world coordinate systems (WCS) in the headers of the most common astronomical image formats, FITS and IRAF .imh, to relate image pixels to sky coordinates*. This software is all written in very portable C, so it should compile and run on any computer with a C compiler. The current (2011) version is 3.8.1

The current version is 3.8.4

	<ul style="list-style-type: none"> Handles all FITS image data types: 8-bit unsigned integer, 16- and 32-bit signed integer, 32- and 64-bit IEEE floating point, plus non-standard 16-bit unsigned integer (BITPIX=16). Accesses IRAF .imh (versions 1 and 2) files as well as FITS files. Uses any of several reference catalog formats from CDROMs or identically-structured online files. Uses the standard SAO/NRAO world coordinate system library or Mark Calabretta's WCSLIB library, which defines the proposed FITS WCS standard. Is VAX-compliant. Implements images with more than one WCS. Uses same WCS subroutines as SAOimage, SAOimg, ds9, and skycat image browsing programs. Can be installed as an IRAF package.
	<ul style="list-style-type: none"> Image WCS (imwcs) (rmwsc) (skz2w2) (w22sk2) (SAOimage) (Setting Good Coordinates) Catalogs and Image WCS (mcat) (mcatd) (Environment Variables) Image Header Utilities (ghdhead) (ghdhead) (mhead) (keyhead) (gethead) Image Utilities (getfit) (getpa) (g2d) (nextfit) (astpa) (sumpa) Catalog Utilities (mcat) (mcat) (skycat)
	<ul style="list-style-type: none"> USNO-B1.0 Catalog HST UGC II HST UGC and GSC-ACT Catalogs USNO-A2.0, SA2.0, and UCAC2 Catalogs 2MASS Point Source Catalog Copenhagen USNO Tycho-2 Catalog Local catalogs in Stardust, ASECII, or SAO TDC binary format Environment variables for catalog paths
	<ul style="list-style-type: none"> World Coordinate System Subroutines Source Catalog Access Subroutines Image I/O and Access Subroutines Processing Subroutines
	<ul style="list-style-type: none"> Anonymous FTP from ftp://tdcftp.harvard.edu/pub/gsc/WCSTools/ (A legitimate domain name is needed as the password, if you have problems retrieve the package via http.) HTTP from http://tdc-www.harvard.edu/software/wcstools/wcstools-3.8.4.tar.gz You can retrieve a subset of the WCSTools subroutines which are needed for WCS conversion from http://tdc-www.harvard.edu/software/wcstools/wcstools-3.8.4.tar.gz If you are on a CP-managed system at the CJA, add /data/otv/wcs/bin/redhat for Redhat Linux machines to your search path. Pete Ratliff has put together a Perl interface to the WCSTools libraries called <i>Astro-WCS-lib-WCS-0.90</i>.
	<ul style="list-style-type: none"> WCS subroutines: D.Mink (1995), ADASS V [full text] Entire package: D.Mink (2001), ADASS XI, D.Mink (1996), ADASS VI [full text] D.Mink (1998), AAS/DDA meeting, D.Mink (1998), ADASS VIII [full text]
	Some subroutines in the library have been adapted and amplified from software originally written by Elwood Downey of the University of Iowa Automated Telescope Facility, Bill Cotton of the U.S. NRAO, Mark Calabretta of the Australian CSIRO, and Pat Wallace of the UK Starlink Project. Others are translated from the Fortran code I wrote to support the star and skyimg programs.
	This software was originally inspired by the impending standardization of WCS keywords in FITS as discussed at the 1994 ADASS Conference. The subroutines to translate between sky and image coordinates came first, then the utilities to use them, and then the programs to search catalogs and fit a world coordinate systems to images.

Last updated 30 December 2011 by [Jessica Mink](mailto:jmink) [email]

Figure 14. Snapshot of WCSTOOL applications.

6. PLANETARIUMS SOFTWARE

6.1 CELESTIA (<http://www.shatters.net/celestia/index.html>) is a free *real-time space simulation* that lets you visually experience our universe in three dimensions.

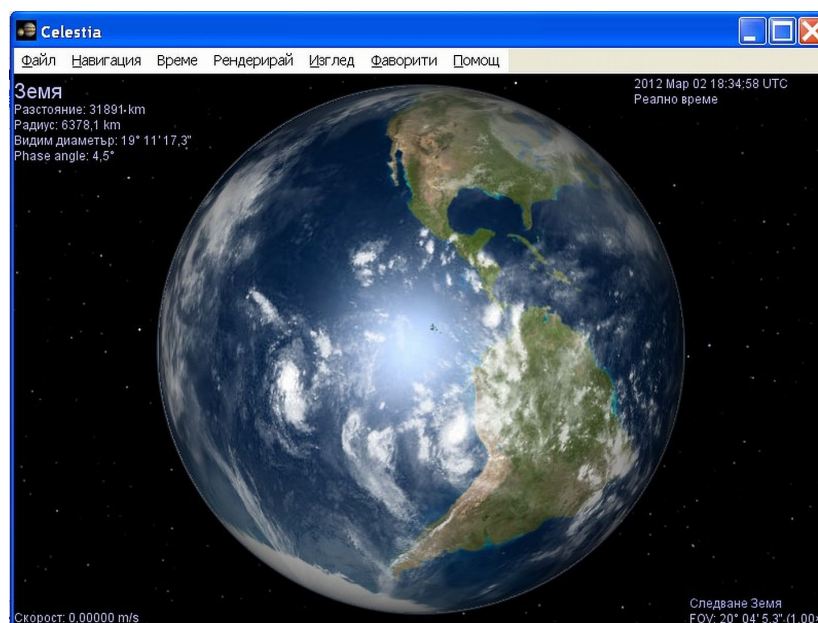
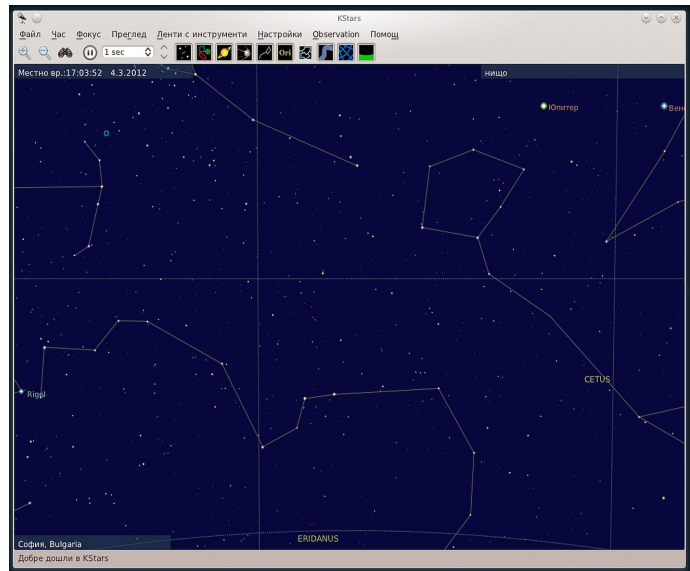


Figure 15. Snapshot of CELESTA planetarium software.

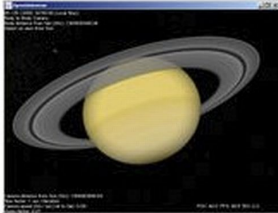
6.2 KSTARS

(<http://edu.kde.org/applications/all/kstars/>) - a *Desktop Planetarium for KDE*. It provides an accurate graphical simulation of the night sky, from any location on Earth, at any date and time. *The display includes upto 100 million stars, 13,000 deep-sky objects, all 8 planets, the Sun and Moon, and thousands of comets and asteroids.*

Figure 16. Snapshot of KSTARS planetarium software.



6.3 OPEN UNIVERSE (<http://openuniverse.org/>)



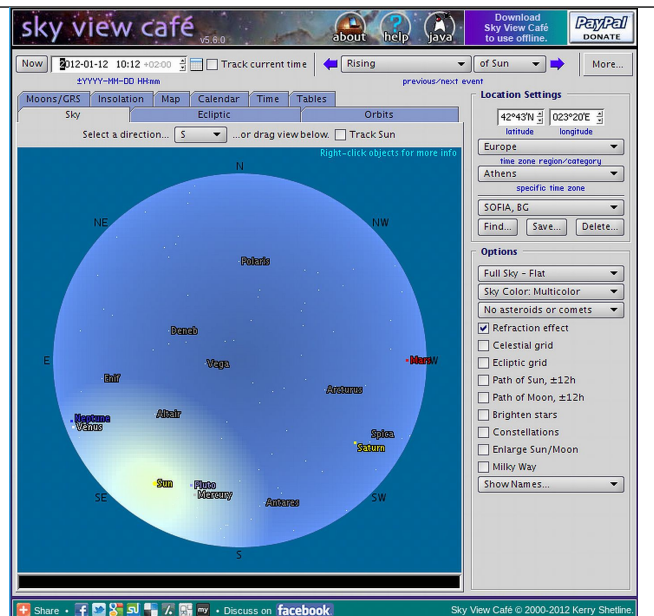
Open Universe

Strictly spoken it's a piece of software, simulating the Solar System's bodies in 3D on your Windows or Linux PC (will work in most *NIX's as well). In difference to quite a few other programs it does so in realtime. Meaning you can view all the planets, moons and spaceships *move* along their paths, trace them, follow them, orbit them and even control them (time and spaceship control). And you won't have to fight your way through hordes of green, slimy and one-eyed aliens for that ;-)

Figure 17. Snapshot of OPEN UNIVERSE home page.

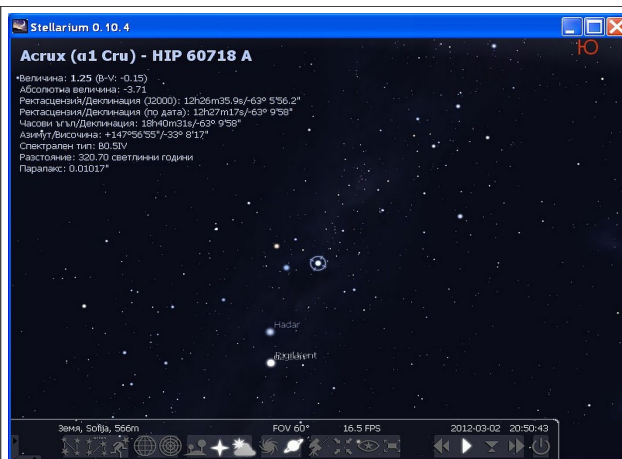
6.4 SKYVIEW.CAFE (<http://circumnavigational/>) - Sky View Cafe is a *Java applet that lets you see many types of astronomical information in both graphical and numerical form*. Sky View Café includes star charts, a 3-D orderly, displays of the moons of Jupiter and Saturn, an astronomical event calendar, an ephemeris generator, and many other features. Author - Kerry Shetline (2000-2010).

Figure 18. Snapshot of SKYVIEW.CAFE planetarium software.



6.5 STELLARIUM (<http://www.stellarium.org/>) - a free open source planetarium for your computer. It shows a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope. It is being used in planetarium projectors. *Stellarium includes: default catalogue of over 600,000 stars; extra catalogues with more than 210 million stars; asterisms and illustrations of the constellations; constellations for twelve different cultures; images of nebulae (full Messier catalogue); realistic Milky Way; very realistic atmosphere, sunrise and sunset; the planets and their satellites.*

Figure 19. Snapshot of STELLARIUM planetarium software.



6.6 XEPHEM (<http://www.clearskyinstitute.com/xephem/>) - a *scientific-grade interactive astronomical ephemeris package*. XEphem: *computes* heliocentric, geocentric and topocentric information for all objects; has built-in support for all planets; the moons of Mars, Jupiter, Saturn, Uranus and Earth; downloads Digitized Sky Survey FITS files from STScI or ESO overlaid with database symbols and other graphical information; provides a handy coordinates spreadsheet for converting among equatorial, ecliptic, horizon and galactic frames; performs automatic star pattern matching to automatically solve for World Coordinate System on any image and many others. Author - Elwood Downey. Copyright'2005 by Robert Bruce Thompson and Barbara Fritchman Thompson.

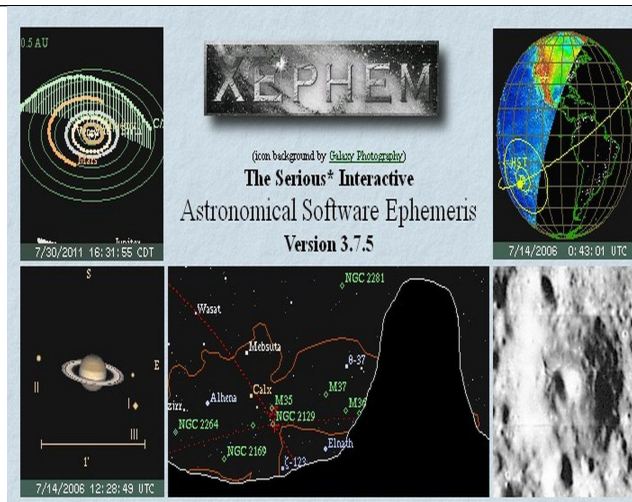
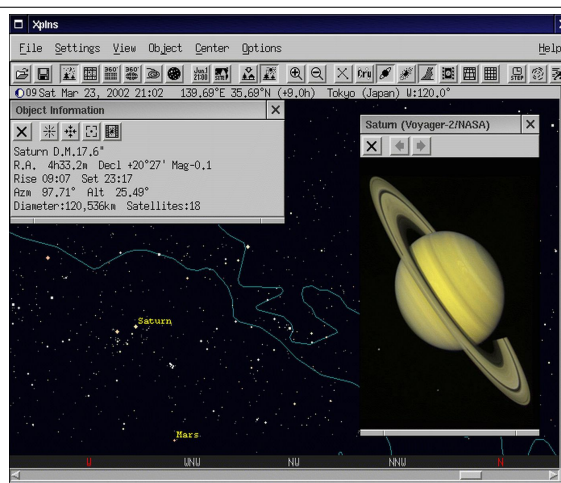


Figure 20. Snapshot of XEPHEM planetarium software.

6.7 XPLNS (<http://www.astroarts.com/products/xplns/index.html>) - reproduces real starry sky on your display of X Window System. It *calculates the position of many celestial objects (stars, galaxies, nebulae, constellations, planets, comets, etc.) very accurately*. There are *fourteen projection mode* in xplns, "Horizontal View Mode", "Equatorial Mode", "Ecliptic Mode", "Galactic Mode", "Planisphere Mode" and "Solar System Mode". Author - AJIKI Osamu.

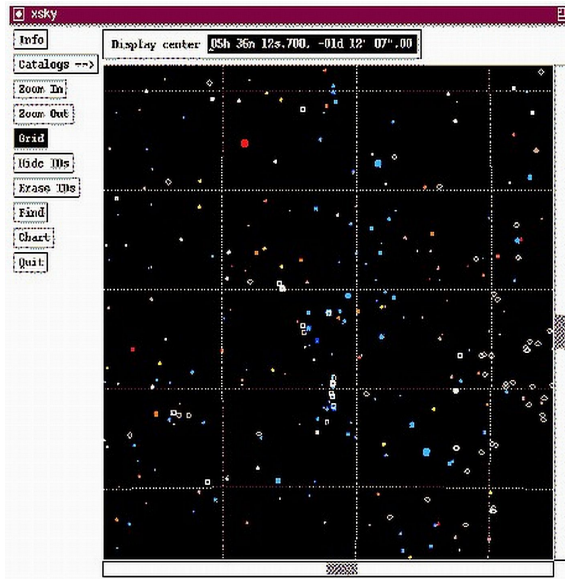
Figure 21. Snapshot of XPLNS planetarium software.



6.8 XSKY

(<ftp://arizona.edu/software/unix/xsky/>;
<http://hpux.connect.org.uk/hppd/hpux/X11/Viewers/xsky-2.01/>) - *makes the use of machine-readable astronomical object catalogues* available by the National Space Sciences Data Centre. Author - T.R.Friedrichsen, Sunquest Information Systems.

Figure 22. Snapshot of XSKY planetarium software.



6.9 XVMOONTOOL (<http://www.paganlink.org/library/astronomy/xvmoontool.html>) - application which *displays information about the moon in real time*. Authors - John Walker and Ron Hitchens.

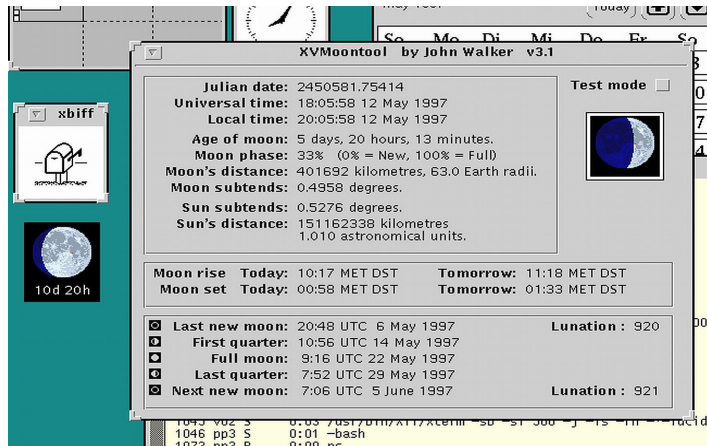
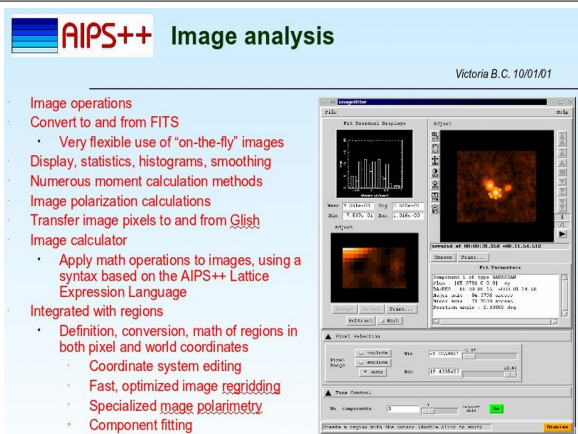


Figure 23. Snapshot of XVMOONTOOL application.

7. RADIO&INTERFEROMETRY ANALYSIS SOFTWARE

7.1 AIPS - stands for Astronomical Image Processing System for *calibration, data analysis, image display, plotting, and a variety of ancillary tasks on astronomical data*. AIPS is *not recommended for processing mm-wave observations* (30 GHz and higher) from the ATCA, e.g. One should use the MIRIAD package instead. (<http://aips2.nrao.edu>;
<http://www.aips.nrao.edu/index.shtml>)

Figure 24. Snapshot of AIPS++ working area.



7.2 ASAP (<ftp://ftp.atnf.csiro.au/pub/software/asap/current/>; <http://svn.atnf.csiro.au/trac/asap>) - an ATNF *Spectral line Analysis package* to reduce single dish, single-pointing spectral-line observations (Marquarding M.: 2009, Astroinformatics School 2009)

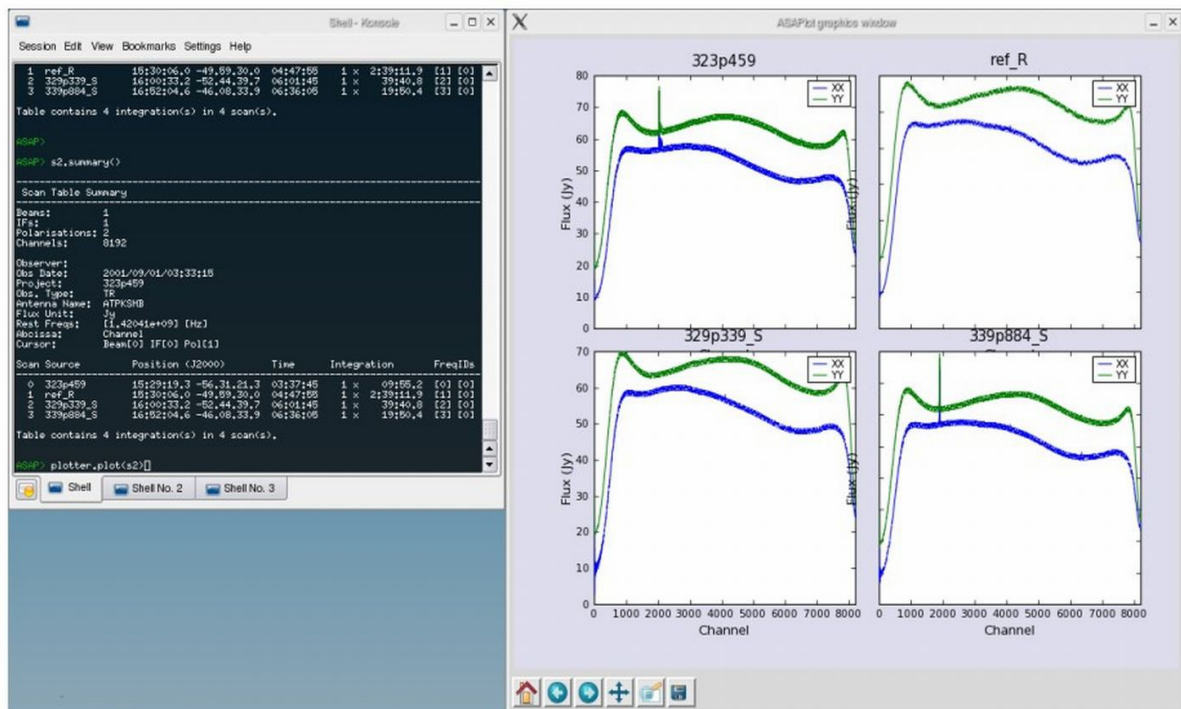


Figure 25. Snapshot of ASAP working area.

7.3 GILDAS (<http://pdb.finkproject.org/pdb/package.php/gildas>; <http://www.iram.fr/IRAMFR/GILDAS/gildas.html>)- Grenoble Image and Line Data Analysis Software.

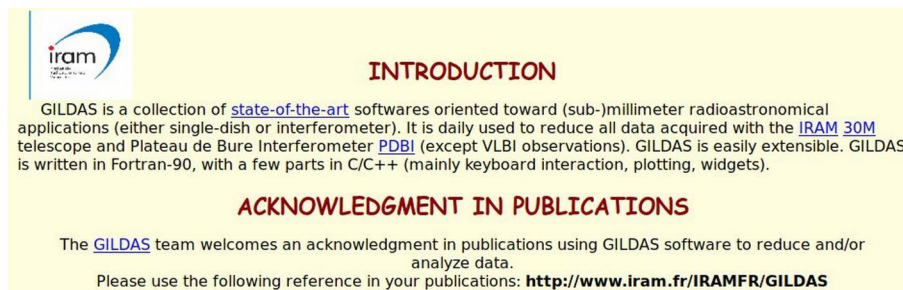


Figure 26. Snapshot of GILDAS home page.

7.4 GIPSY (<http://www.astro.rug.nl/~gipsy/>; <http://www.atnf.csiro.au/computing/software/gipsy/>) - a highly interactive software system for the *reduction and display of astronomical data*.

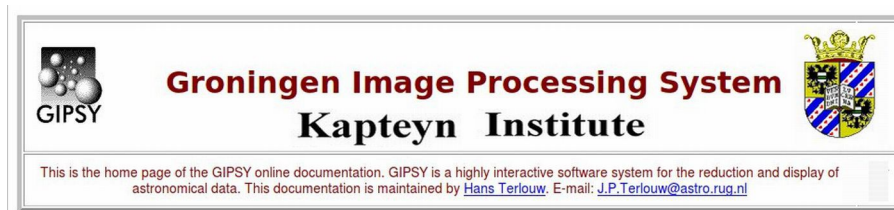


Figure 27. Snapshot of GIPSY home page.

7.5 MIRIAD (<ftp://ftp.atnf.csiro.au/pub/software/miriad/>) - radio interferometry reduction package e.g. of continuum and spectral line observations...

7.6 SPC (<http://www.atnf.csiro.au/computing/software/spc/>; <ftp://ftp.atnf.csiro.au/pub/software/spc/>) - a **Spectral Line Reduction Package** used for reducing spectral line data from the Parkes and Mopra radiotelescopes. SPC was originally written to process data written by SPECTRA, the spectral-line observing program of the Parkes radiotelescope. The basic idea in using SPC is to **load in a sequence of up to 110 spectra and then use various commands to operate on these spectra**. Author - Rick Forster.

7.7 SPEXtool (<http://irtfweb.ifa.hawaii.edu/~spex/>) – an IDL-based package for the **reduction of spectral data obtained with SpeX IR imager and spectrograph** (Rayner et al. 2004, Cushing et al. 2004).

8. SPECTRUM ANALYSIS

8.1 DIPSO.STARLINK (<http://www.starlink.rl.ac.uk/star/docs/sun50.htx/sun50.html>) - DIPSO is, historically, **a simple plotting package incorporating some basic astronomical applications**. **DO read the documentation fully at some time; DIPSO can do a lot of things, some of which you might not know that you needed** until you read about them... (by I. D. Howarth, J. Murray, D. Mills & D. S. Berry, 5.03.2004)

8.2 ICUR.IDL (<http://www.astro.sunysb.edu/fwalter/ICUR/icur.tar.gz>) - a generalized program which permits the user **to display and measure spectra**. Written in IDL, ICUR is a cursor-oriented spectral display and analysis program.

8.3 PINTOFALE (<http://hea-www.harvard.edu/PINTofALE/>) - originally developed to **analyze spectroscopic data from optically-thin coronal plasmas**, though much of the software is sufficiently general **to be of use in a much wider range of astrophysical data analyzes** (Kashyap & Drake 2000).

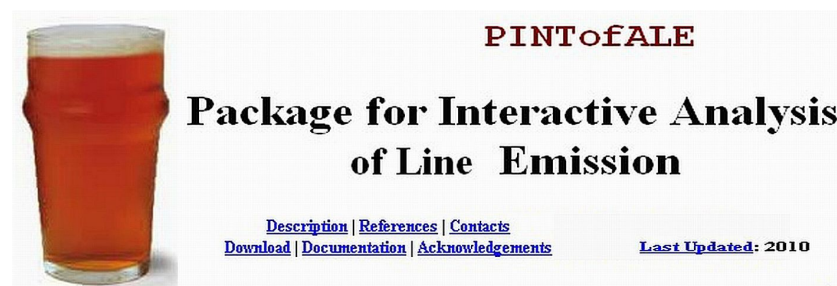


Figure 28. Snapshot of PINTOFALE home page.

8.4 SHERPA (<http://cxc.harvard.edu/sherpa4.3/index.html>)



Figure 29. Snapshot of SHERPA home page.

Sherpa enables the user *to construct complex models from simple definitions and fit those models to data, using a variety of statistics and optimization methods*. Sherpa lets you:

Fit 1-D data sets (simultaneously or individually), *including*: spectra, surface brightness profiles, light curves, general ASCII arrays; access the internal data arrays; build complex model expressions; import and use your own models; choose appropriate statistics for modeling Poisson or Gaussian data; import new statistics, with priors if required by analysis; visualize a parameter space with simulations or using 1-D/2-D cuts of the parameter space; calculate confidence levels on the best-fit model parameters; etc... (Freeman et al. 2001).

Figure 30. Snapshot of SHERPA modeling examples.

Sherpa lets you:

- fit 1-D data sets (simultaneously or individually), including: spectra, surface brightness profiles, light curves, general ASCII arrays;
- fit 2-D images/surfaces in the Poisson/Gaussian regime;
- access the internal data arrays;
- build complex model expressions;
- import and use your own models;
- choose appropriate statistics for modeling Poisson or Gaussian data;
- import new statistics, with priors if required by analysis;
- visualize a parameter space with simulations or using 1-D/2-D cuts of the parameter space;
- calculate confidence levels on the best-fit model parameters;
- choose a robust optimization method for the fit: Levenberg-Marquardt, Nelder-Mead Simplex or Monte Carlo/Differential Evolution;
- and use Python to create complex analysis and modeling functions, build the batch mode analysis or extend the provided functionality to meet the required needs.

8.5 SNID (<http://marwww.in2p3.fr/~blondin/software/snid/index.html>) – a software to determine the type, redshift, and age of a type Ia supernovae (Blondin & Tonry 2007).

8.6 SPECTRUM (<http://www1.appstate.edu/dept/physics/spectrum/specftp.html>) - currently, *SPECTRUM is suitable for computing stellar spectra in the spectral-type range B – mid M*. Copyrighted by Richard O. Gray, 1992-2008.

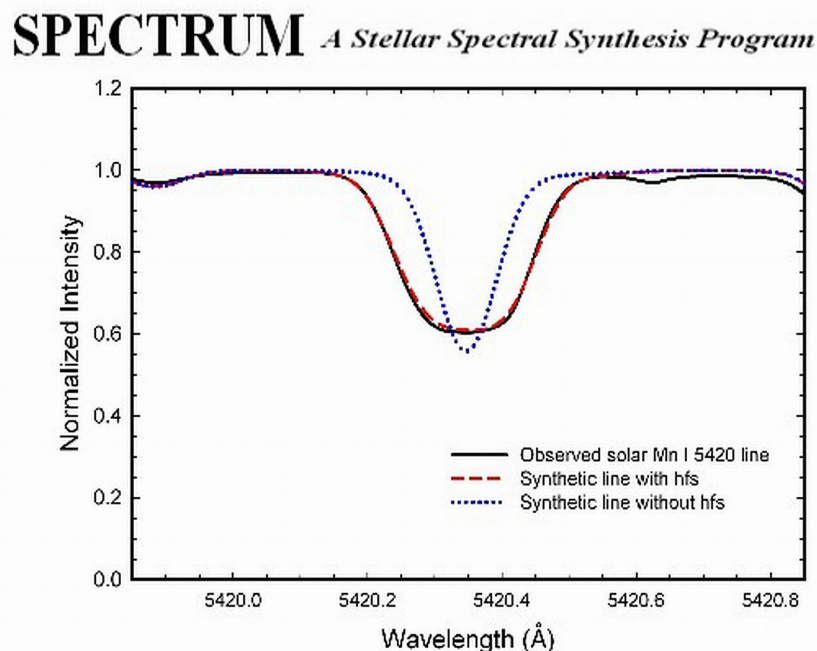


Figure 31. Snapshot of SPECTRUM application.

8.7 SPECVIEW (http://www.stsci.edu/institute/software_hardware/specview/) - a tool for 1-D spectral visualization and analysis of astronomical spectrograms.

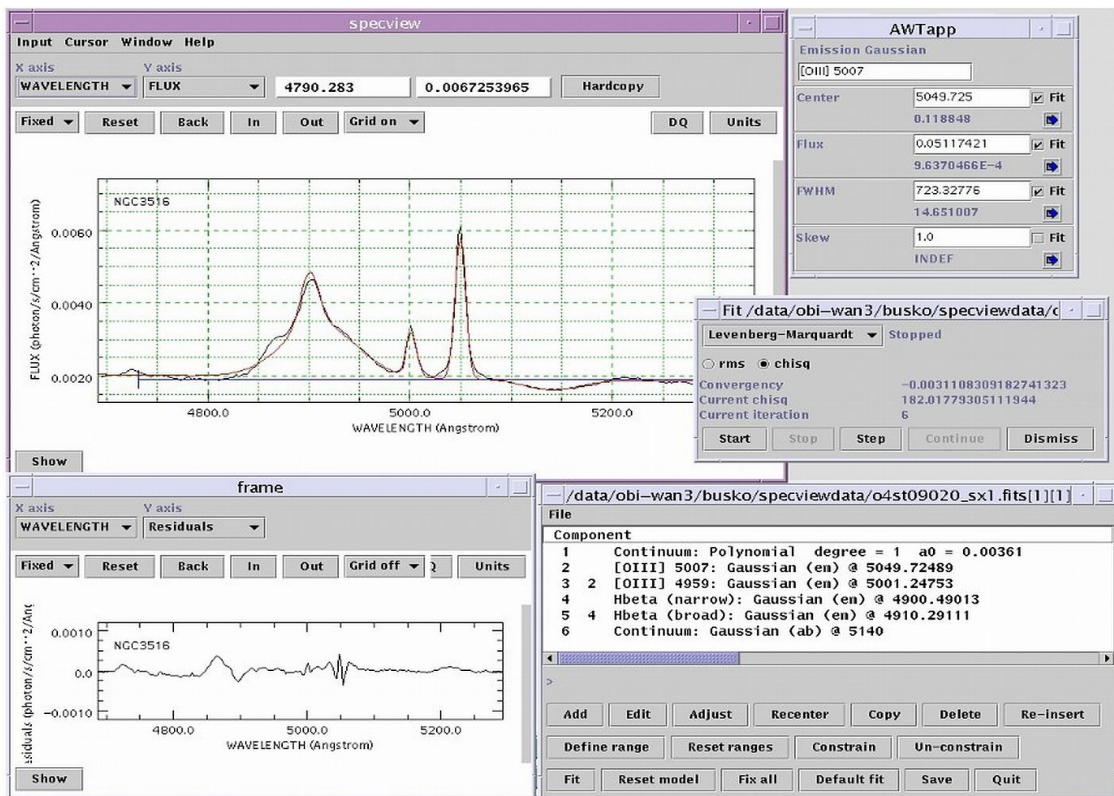


Figure 32. Snapshot of SPECVIEW working area.

8.8 SPLAT - a graphical tool for displaying, comparing, modifying and analyzing astronomical spectra stored in NDF, FITS and TEXT files as well as the new NDX format.

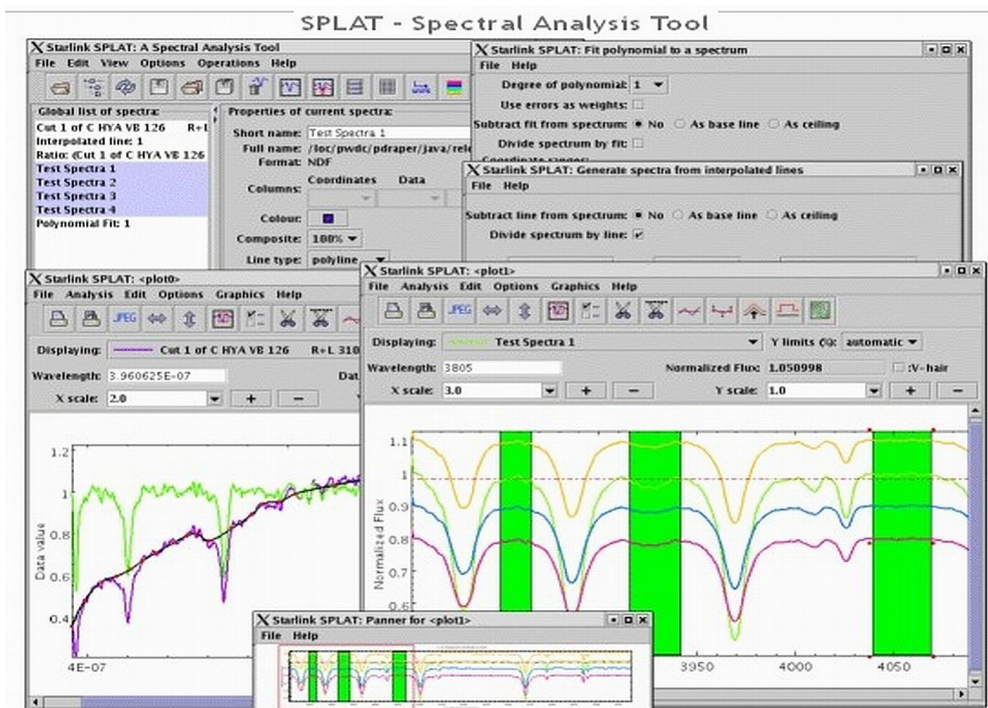


Figure 33. Snapshot of SPLAT working area.

8.9 STECKMAP (<http://astro.u-strasbg.fr/~ocvirk/indexsteckmap.html>) - a powerful toolkit for whoever wishes to interpret the stellar absorption features of integrated light spectra of stellar populations. It is

written in *yorick* (Ocvirk et al. 2006A, 2006b).

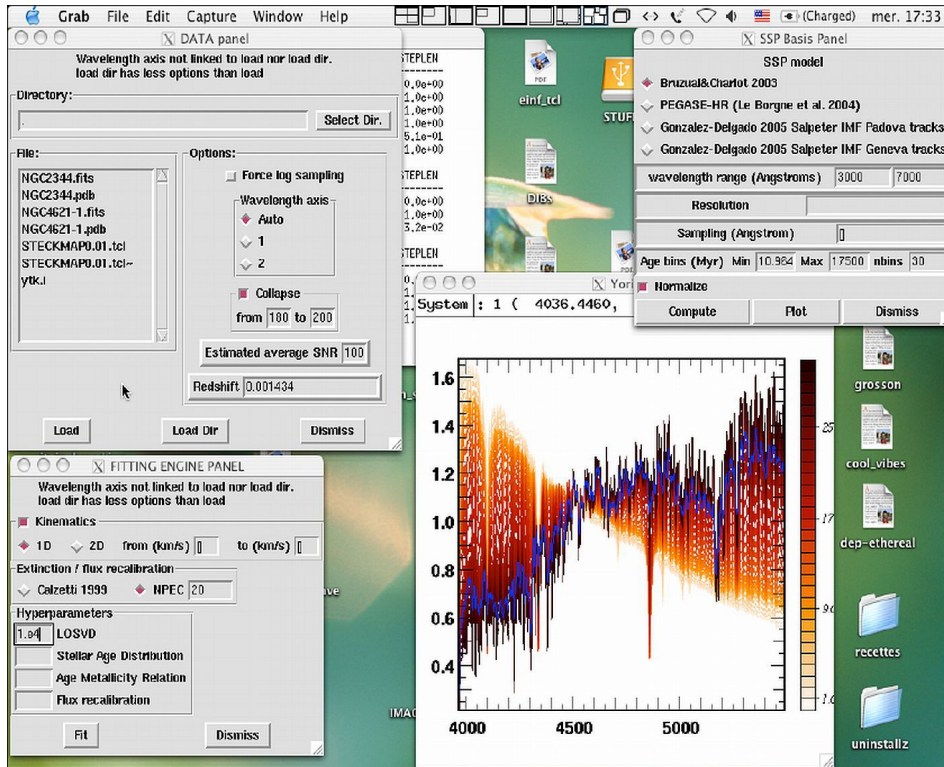


Figure 34. Snapshot of STECKMAP working area.

8.10 XSTAR (<http://heasarc.gsfc.nasa.gov/docs/software/lheasoft/xstar/xstar.html>) - a command-driven, interactive, computer program for *calculating the physical conditions and emission spectra of photoionized gases*.

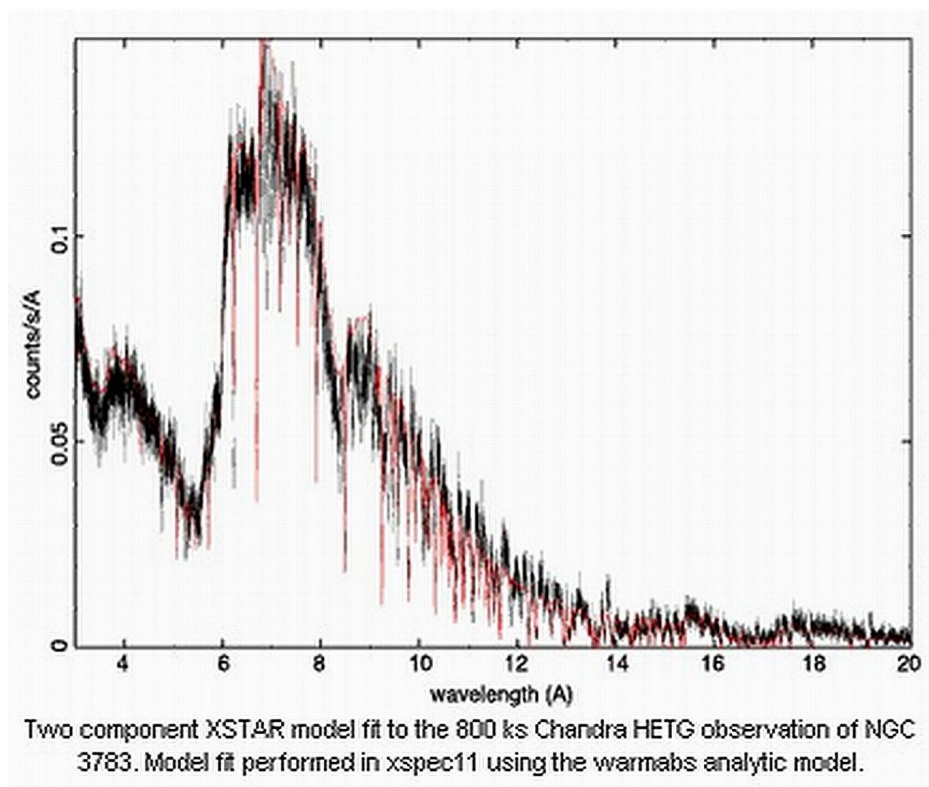
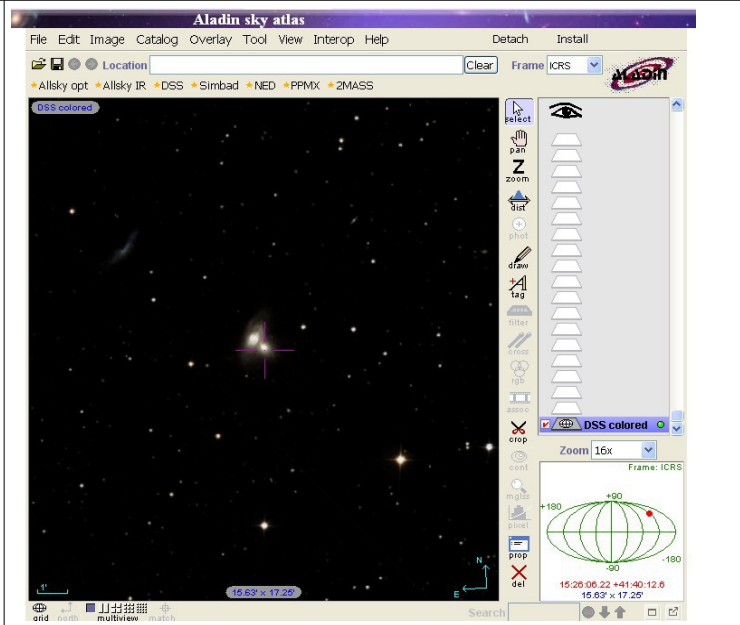


Figure 35. Snapshot of XSTAR application.

9. VISUALIZATION SOFTWARE

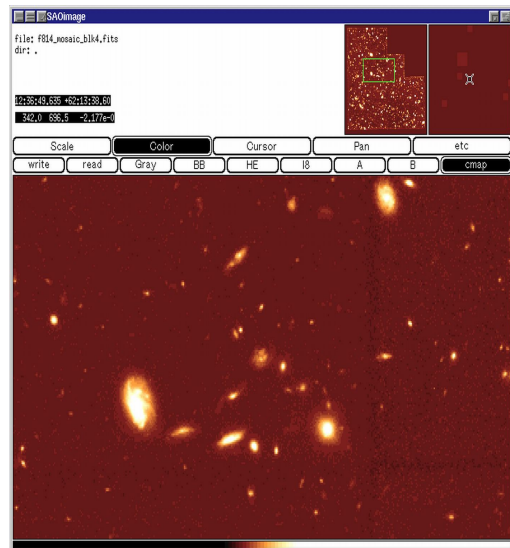
9.1 ALADIN (<http://aladin.u-strasbg.fr/>) - An *interactive software sky atlas* allowing the user to visualize digitized astronomical images, superimpose entries from astronomical catalogues or databases, and interactively *access related data and information from the Simbad database, the Vizier service and other archives for all known sources in the field* (Bonnarel et al. 2000).

Figure 36. Snapshot of ALADIN application.



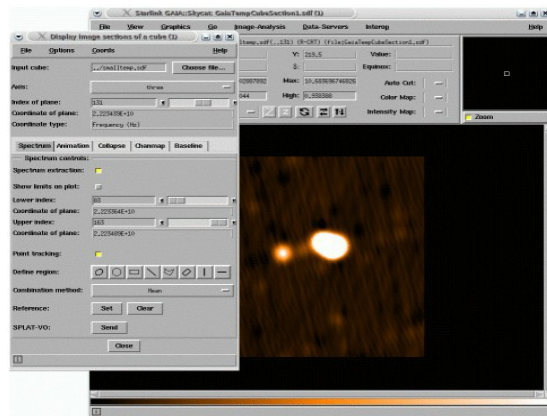
9.2 DS9 (<http://hea-www.harvard.edu/saord/ds9/>) - *SAO Image DS9 is an astronomical imaging and data visualization application*. DS9 supports FITS images and binary tables, multiple frame buffers, region manipulation, and many scale algorithms and colormaps. It provides for easy communication with external analysis tasks and is highly configurable and extensible via XPA and SAMP. DS9 is a stand-alone application. *It requires no installation or support files*. DS9 also supports FTP and HTTP access.

Figure 37. Snapshot of SAOimage DS9 application.



9.3 GAIA-ESO (<http://extraterritorial/~pdraper/gaia/ontheweb/index.html>)

Figure 38. Snapshot of GAIA SkyCat application.



9.4 FUSE.IDL (<http://fuse.pha.jhu.edu/analysis/sw/>) - **IDL widget programs for displaying and manipulating FUSE data files**, written by Don Lindler. There are many features in this program for manipulating time-tag data. The following programs for the reading and display of FUSE images and spectra have been contributed at JHU: **ftv.pro**; **readit.pro**; **plotrate.pro**; **showdetector.pro**; **allsegments.pro**; **hist_combine**. Authors: Alex Fullerton, Don Lindler, Ed Murphy, Bill Oegerle, Dave Sahnaw.

9.5 FV FITS VIEWER (<http://heasarc.gsfc.nasa.gov/docs/software.html>)

Fv: The Interactive FITS File Editor


The latest version is 5.3, released July 2009

Fv is the easy to use graphical program for viewing and editing any FITS format image or table. The Fv software is small, completely self-contained and ready to run on

- Windows PCs
- Most Unix platforms
- Mac OS-X

Fv can be used with the DS9 image display.

[Download Fv now...](#)

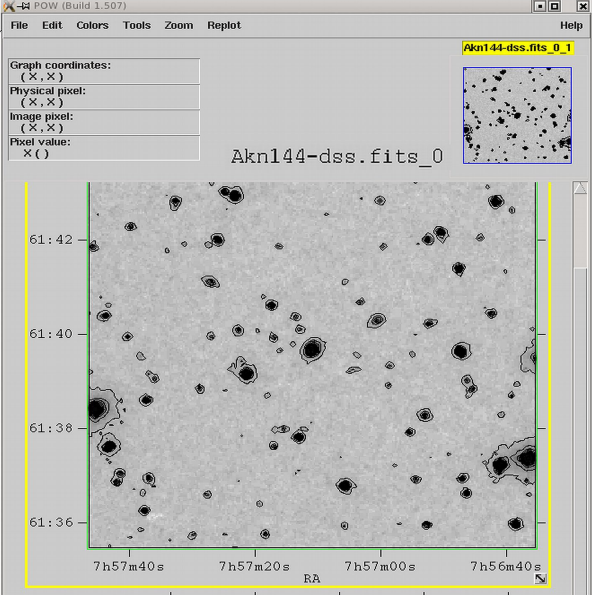


The FITsview family consists of viewers for astronomical images in FITS format. Viewers are available for MS-Windows, Macintosh and Unix systems and offer a wide variety of image display features. The FITsview programs are distributed free of charge by the (USA) National Radio Astronomy Observatory. These programs are Y2K compliant.

**FITsview
for Windows**

**FITsview
for Macintosh**

**FITsview
for Unix**



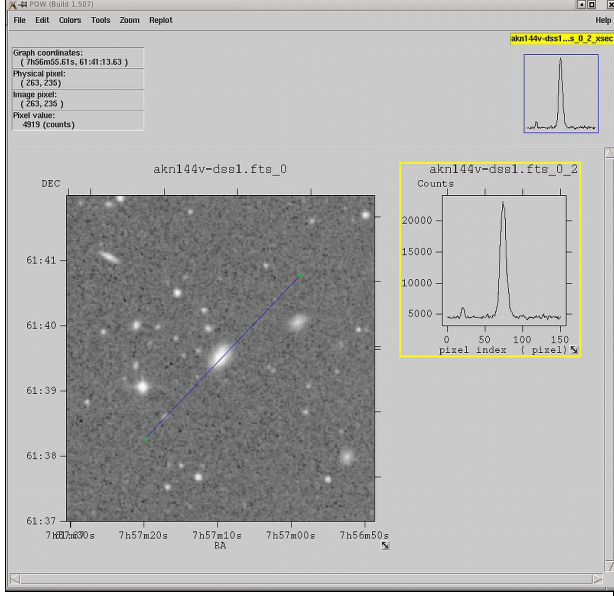


Figure 39a,b,c,d. Snapshot of fv FITS file editor application.

9.6 KARMA TOOLKIT (<ftp://ftp.atnf.csiro.au/pub/software/karma/>) - **A package for visualization multi-dimensional images, signal and image processing applications** (Gooch 1996).

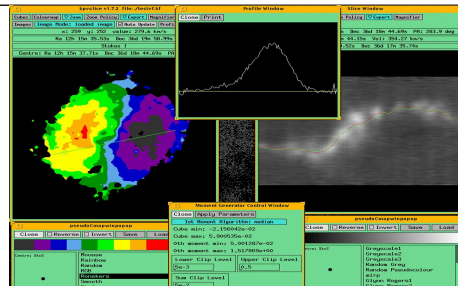


Figure 40. Snapshot of KARMA toolkit application.

9.7 PROFIT (<http://heasarc.gsfc.nasa.gov/docs/software/profit/>) - a GUI (graphical user interface) *tool for accessing high-resolution spectra*. Profit displays spectra in various formats, allowing users to identify emission lines, to convert an identified line into velocity units using a user-selected wavelength, to store (and restore) individual spectra, to fit lines to gaussians, and other features.

9.8 QFITSVIEW (<http://www.mpe.mpg.de/~ott/dpuser/qfitsview.html>). Copyrighted by Thomas Ott.



Figure 41. Snapshot of QFITSVIEW application.

9.9 SDSS.SKYSERVER (<http://cas.sdss.org/dr7/en/>) - the *data access site for the Sloan Digital Sky Survey*. From the site, one can view all of the SDSS data, using the same tools that professional astronomers use etc.

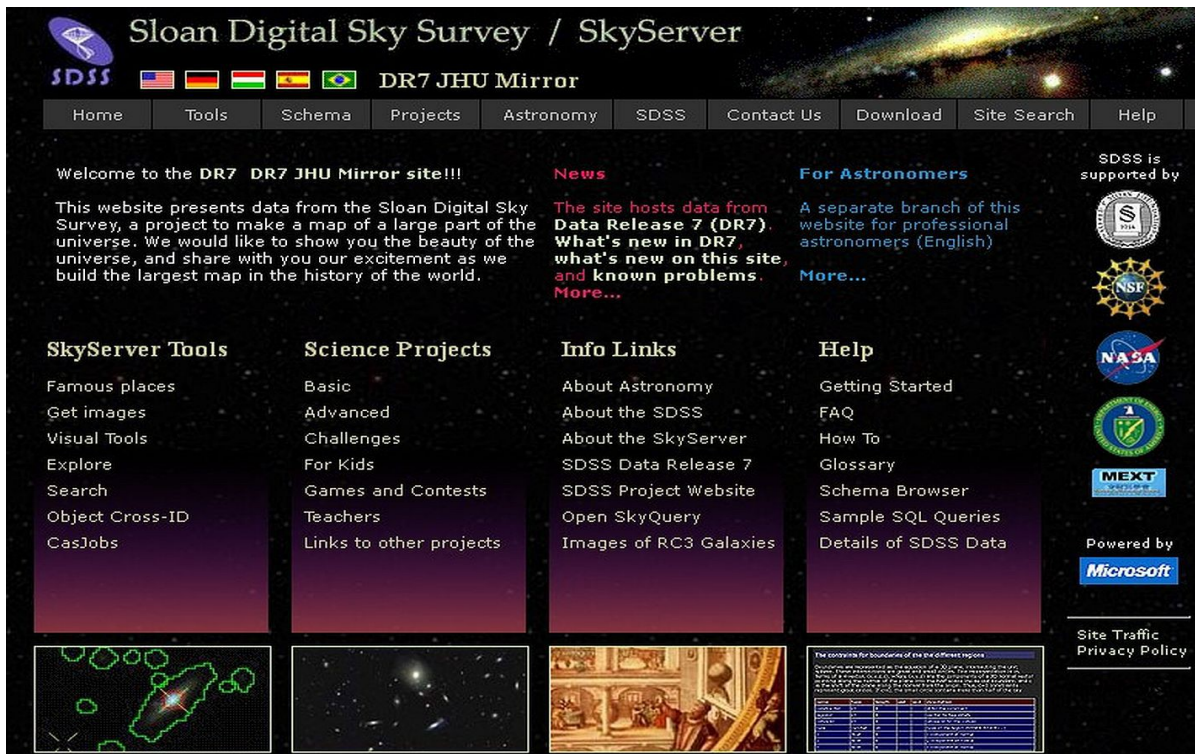


Figure 42. Snapshot of SDSS.SKYSERVER home page.

9.10 SKYCAT-ESO (<http://archive.eso.org/cms/tools-documentation/skycat>) - a tool that *combines visualization of images and access to catalogs and archive data* for astronomy. Below is Java SkyCat application

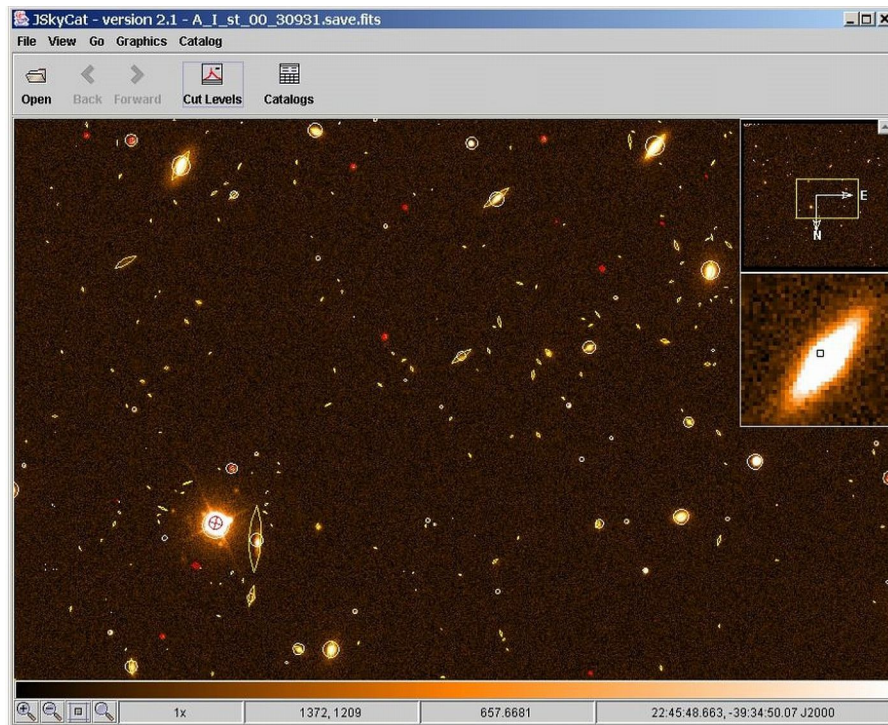


Figure 43. Snapshot of SKYCAT-ESO application.

9.10 SKYMAP (<http://tdc-www.harvard.edu/software/skymap/>) - an *astronomical mapping program* written in Fortran and C for Unix workstations by Doug Mink of the Smithsonian Astrophysical Observatory Telescope Data Center (Mink 1993).

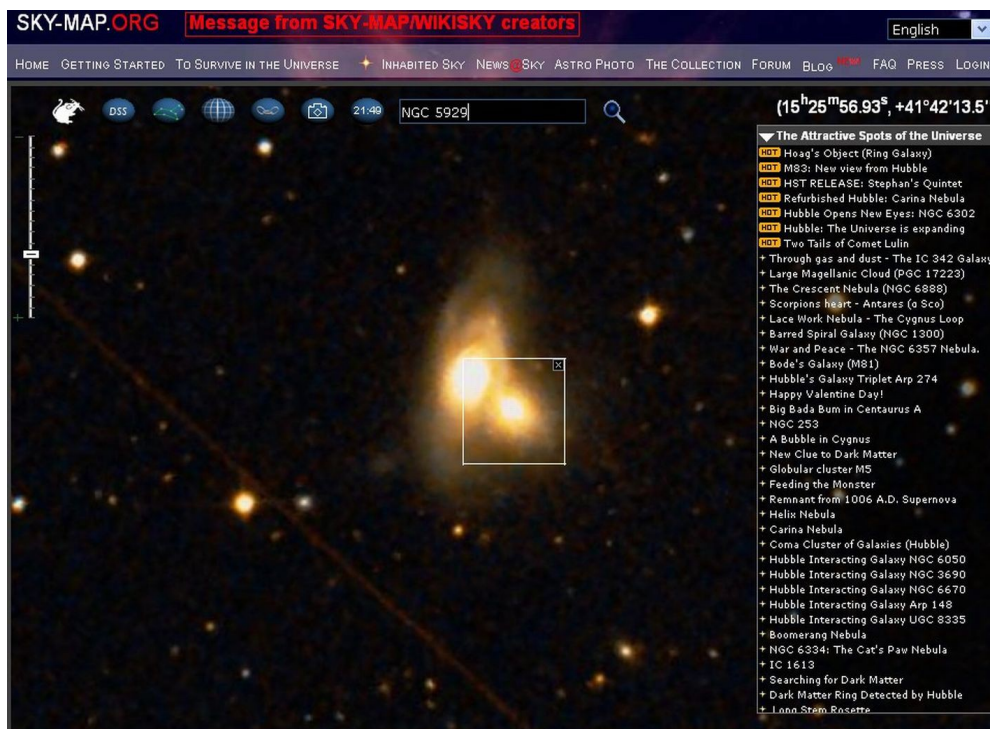


Figure 44. Snapshot of SKYMAP application.

9.12 VIRGO (<http://archive.eso.org/cms/virgo/>)



VirGO is the next generation Visual Browser for the ESO Science Archive Facility developed by the VO Systems Department. It is a plug-in for the popular open source software [Stellarium](#) with added capabilities for browsing professional astronomical data. VirGO gives astronomers the possibility to easily discover and select data from millions of observations in a new visual and intuitive way. Its main feature is to perform real-time access and graphical display of a large number of observations by showing instrumental footprints and image previews, and to allow their selection and filtering for subsequent retrieval. It reads FITS images and catalogues in VOTable format. It superimposes DSS background images and allows to view the sky in a *real life* mode as seen from the main ESO sites.

Data interfaces are based on Virtual Observatory [standards](#) enabling access to images and spectra hosted by other data centers and to exchange data with other VO applications through the [PLASTIC](#) messaging system.

These screenshots illustrate some of the main features of VirGO such as footprints, DSS background, previews or browsing through large number of data sets.

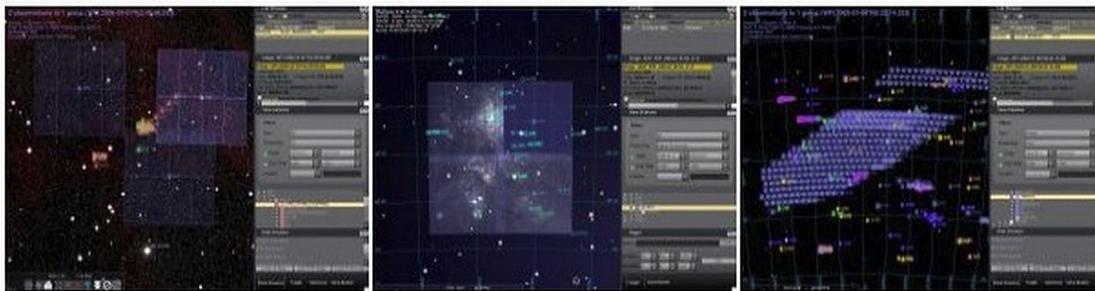


Figure 45. Snapshot of ESO VIRGO application.

9.13 VISIT (<https://wci.llnl.gov/codes/visit/home.html>) - an interactive parallel visualization and graphical analysis tool for viewing scientific data. Users can quickly generate visualizations from their data, animate them through time, manipulate them, and save the resulting images for presentations. VisIt contains a rich set of visualization features so that you can view your data in a variety of ways. It can be used to visualize scalar and vector fields defined on two- and three-dimensional (2D and 3D) structured and unstructured meshes. VisIt was designed to handle very large data set sizes in the terascale range and yet can also handle small data sets in the kilobyte range. VisIt handles 2D and 3D data equally well. VisIt also has the ability to animate data, allowing users to see the time evolution of their data. VisIt is also a powerful analysis tool. It provides support for derived fields, which allow new fields to be calculated using existing fields.

10. VO SOFTWARE - details presented during the VII_SBAC (Petrov et al. 2012)

10.1 ESO-MEX (<http://cds.u-strasbg.fr/twikiDCA/bin/view/EuroVODCA/DcaJune2008ESOMEx>) - tools for publishing images and spectra

10.2 SAADA (<http://amwdb.u-strasbg.fr/saada/>) - transforms a set of heterogeneous FITS files or VOTables of various categories (images, tables, spectra....) into a database.

10.3 DAL ToolKit (<http://www.ivoa.net/cgi-bin/twiki/bin/view/IVOA/IvoaDAL>;
<http://www.sciops.esa.int/SD/ESAVO/DALToolKit-v0.0.tar.gz>)

10.4 DATASCOPE (<http://heasarc.gsfc.nasa.gov/cgi-bin/vo/datascope/>) - searches everything for a given target or region of the sky.

10.5 MAKI (http://heasarc.nasa.gov/docs/astroe/prop_tools/maki.html) - investigates instrument Fields of View (FOV's), and viewing multi-mission observing windows.

10.6 PLASTIC (<http://esavo.esac.esa.int/VOSpecManual/interoperability.html>) - a protocol for communication between client-side astronomy applications.

10.7 SKYVIEW (<http://skyview.gsfc.nasa.gov/>) - generating all sky images from Radio to Gamma-Ray

- 10.8 SPECVIEW** (http://www.stsci.edu/institute/software_hardware/specview/) - a tool for 1-D spectral visualization and analysis of astronomical spectrograms (see 8.7 too).
- 10.9 SPLAT** (<http://star-www.dur.ac.uk/~pdraper/splat/splat.html>) - a toolbox for querying, downloading and displaying spectra from the current generation of SSAP servers.
- 10.10 STILTS** (<http://www.starlink.ac.uk/stilts/>) - a set of command-line tools processing astronomical tables. Author - Mark Taylor.
- 10.11 TOPCAT** (<http://www.starlink.ac.uk/topcat/>) - an interactive graphical viewer and editor for tabular data. Author - M. Taylor.
- 10.12 VisIVO** (<http://visivo.oact.inaf.it/>) - a visualization and analysis software for astrophysical data
- 10.13 VOCONVERT** (<http://vo.iucaa.ernet.in/~voi/VOConvert.htm>) - a tool for converting files from one format to another
- 10.14 VODESKTOP** (<http://www.astrogrid.org/wiki/Help/IntroVODesktop>) - a core application with several interlinked tools
- 10.15 VOEVENT** (<http://www.ivoa.net/Documents/VOEvent/>) - a standardized language used to report observations of astronomical events
- 10.16 VOPLOT** (<http://vo.iucaa.ernet.in/~voi/voplot.htm>) - a tool for visualizing astronomical data.
- 10.17 VOSA** (<http://svo.cab.inta-csic.es/theory/vosa/>) - a tool designed to perform the many tasks in an automatic manner (Bayo et al. 2008).
- 10.18 VOSPEC** (<http://esavo.esa.int/vospec/>) - a multi-wavelength spectral analysis tool with access to spectra, theoretical models and atomic and molecular line databases registered in the VO.
- 10.19 VOSTAT** (<http://astrostatistics.psu.edu/vostat/>) - statistical routines on large datasets.

11. X_RAY ANALYSIS SOFTWARE

- 11.1 CIAO** (<http://cxc.harvard.edu/ciao/index.html>) - Chandra Interactive Analysis of Observations. The remarkable science capabilities of the Chandra X-ray Observatory demanded new, *flexible, multi-dimensional software to analyze the data* it returned. A system has been proven itself *useful for the analysis of data from other, non-X-ray missions*, because of the mission independence that is the basis of the CIAO design (Fruscione et al. 2006).
- 11.2 ISIS.XRAY** (<http://space.mit.edu/cxc/isis/>)- a complete package to process CCD images using the *image optimal subtraction method* (Alard & Lupton 1998, Alard 1999). The ISIS package can find the best kernel solution even in case of kernel variations as a function of position in the image. (...see 1.5 too...).
- 11.3 PIMMS** (<http://heasarc.nasa.gov/docs/software/tools/pimms.html>) - **P**ortable, **I**nteractive **M**ulti-**M**ission **S**imulator software *for high-energy astrophysicists*.
- 11.4 SAS** (http://xmm.esac.esa.int/sas/current/documentation/sas_concise.shtml) - The **S**cience **A**nalysis **S**ystem is *a collection of tasks, scripts and libraries, specifically designed to reduce and analyze data collected by the XMM-Newton observatory*. “XMM-Newton data are available in two formats: 1) Observation Data Files (ODF), i.e. reformatted telemetry in FITS format and 2) Pipeline Processing System (PPS) products, a collection of validated, top-level scientific products”.
- 11.5 SPEX** (<http://www.sron.nl/>) - a software package *optimized for the analysis and interpretation of high-resolution cosmic X-ray spectra*. The software is especially suited for fitting spectra obtained by

current X-ray observatories like XMM-Newton, Chandra, and Suzaku.

11.6 XSPEC (<http://heasarc.gsfc.nasa.gov/docs/xanadu/xspec/> - An *X-Ray Spectral Fitting Package*. XSPEC is a command-driven, interactive, X-ray spectral-fitting program, completely detector-independent. XSPEC has been used to analyze data from HEAO-1 A2, *Einstein Observatory*, EXOSAT, Ginga, ROSAT, BBXRT, ASCA, CGRO, IUE, RXTE, Chandra, XMM-Newton, Integral/SPI, Swift and Suzaku (Arnaud 1996).

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