ADASS XV in Spain: The Old Systems Are Dying. Will They Be Reborn in the Virtual Observatory?

Doug Mink
Telescope Data Center
Smithsonian Astrophysical Observatory

http://tdc-www.harvard.edu
San Lorenzo de El Escorial

Rafael Leon for ADASS XV
San Lorenzo de El Escorial

Rafael Leon for ADASS XV
Astronomical Data Analysis
Software and Systems

- Annular Solar Eclipse!
- Old Software systems are losing support
- Scripting and API's are being talked about
- FITS standards moving ahead faster
- Virtual Observatory Update
- Components for scripting
  -> My WCSTools paper
- My To Do List
Annular Eclipse

San Lorenzo de El Escorial was 8 km from center line
Annular Eclipse

After a welcome and the first invited talk on eclipse chasing by Glenn Williams of the University of Arizona, we all went out to a nearby soccer field to watch the event.
Annular Eclipse

You don't need much equipment to observe the sun.
Annular Eclipse

Nature projects the event for you
Annular Eclipse

Eclipse sequence above Alfonso XII monument in Madrid

Copyright © Peter den Hartog 2005
The Setting

In the past few years, support for the major data analysis systems has declined

- Starlink in England is no longer supported
- MIDAS in continental Europe is no longer supported
- IRAF development is pretty much on hold
- NRAO development has moved from AIPS to ALMA
- Will each project develop only for themselves?
A Proposal

Since 1995, there has been a Birds of a Feather meeting at ADASS entitled Future Astronomical Data Systems. It started as sort of an outsider event, but this year the convenors were Doug Tody (NRAO and NVO) and Preben Grosbol (ESO and Opticon).

The European Opticon Network is working with the US NVO to define requirements, general architecture, and interface specifications for a new system which

- Runs on a desktop
- Can run pipeline scripts
- Works with the Virtual Observatory
- Has an open architecture
- Works at all wavelengths
- Is user-programmable
- Is scalable
An Earlier Proposal

From Joe Harrington in 1996:

Ideally, we should all be able to make use of the same analysis, display, and plotting routines. I'll take it a step further and say we should even be able to call routines written by each other in different scripting languages. The idea would be that the system core ... would take care of managing the objects and connecting to dynamically linked modules, including those that handle interpreting the different languages, plotting, etc.
Reality

More than ever, the astronomical community is converging on Python as its scripting language (despite this year's new, improved IRAF ECL and the suggestion from the audience of IDL).

To avoid reinventing the wheel, interfaces to the legacy data analysis systems are being developed:

- Pyraf for IRAF at STScI (and PyFITS, too)
- PyMidas at ESO (as Finnish contribution)
- ParselTongue for AIPS by RadioNet (part of the ALBUS project)
- PyWCS at the CfA?
This Year's Cool Software

- **R** statistical computing package tutorial before meeting, widely-used, extensible

- **SkyBot** web service to find asteroids returns all asteroids in field of view from 1949

- **SCAMP** automatic photometric and astrometric calibration from Emmanuel Bertin (SExtractor)

- Others?
FITS

• FITS MIME types have been approved by IESG
• 64-bit integers have almost been added to standard
• Spectral coordinates paper III has been approved
• Mark Calabretta promises to get back to Paper IV on distortion
• Arnold Rots has promised a draft outline of Paper V on time coordinates by the end of 2005. He is doing similar work for the IVOA
• Mark Calabretta is starting to think about Paper VI on color
Virtual Observatory

• 1/3 of ADASS papers mention VO explicitly; ½ – 2/3 have connection -Bob Hanisch

• In the US, there will be a central NVO facility to manage ongoing US VO operations, curate registries, and serve as the equivalent to an observatory staff

• In Europe, AVO is becoming Euro-VO with its own center, Euro-VO Technology Centre

• ESO, which has one of the largest pipeline-reduced archives, has dedicated staff to putting it into the VO
IVOA Interop

- Protocols are evolving and becoming more useful
- There are new applications and old ones support protocols
- Theoretical data is being incorporated into the VO
- VOEvent uses protocols for near-real-time observation coordination
- Most, but not all, applications are still catalog matching
IVOA Interop

Protocols are evolving

• Simple Spectral Access Protocol (SSAP)
  Moving beyond SEDs: non-photometric spectra are mentioned

• Spectral Line Access Protocol (SLAP)
  New protocol to store catalogs of line positions (to match observation and theory)

• Simple Image Access Protocol (SIAP)
  a new version is being prepared
IVOA Interop

The application session was interesting:

Isa Barbarisi  New functionalities in VOSpec: Spectral Line Access & Theoretical Models

Raúl Gutiérrez  VOSed: a tool for building spectral energy distributions Comparison with theoretical models

Claudio Gheller  VisIVO interoperability with VO enabled tools

Pierre Fernique  Experience gained by enabling Interoperability in Aladin

Francesco Pierfederici  **Python** Tools for the VO Generation

Noel Winstanley  ACR - a VO Client Implementation

John Taylor  VO-enabled xmdv-lite and Plastic
WCSTools 4.0: Building Astrometry and Catalogs into Pipelines

by Douglas Mink

Telescope Data Center
Smithsonian Astrophysical Observatory

http://tdc-www.harvard.edu/software/wcstools/
Abstract

While the WCSTools package was developed to deal with world coordinate systems in FITS image headers, it does a lot more.

• Source catalog extraction and manipulation
• Command line name resolution
• Time and space coordinate conversion
• FITS and IRAF image manipulation

Documentation is at http://tdc-www.harvard.edu/software/wcstools/
Supported Catalogs

- Originally, only the HST Guide Star Catalog was supported
- Digitized Sky Survey extractions were added
- Deep all-sky catalogs have been supported since USNO-A1.0
- Catalogs are supported in their native format through one API
- `scat`, `imcat`, `imwcs`, and `immatch` use a standard catalog interface
Supported Catalogs

Deep All-Sky Catalogs (for recent epoch CCD images)

- **USNO-B1.0 Catalog**: 1,036,366,767 stars, 83 Megabytes, send a hard drive to USNO
- **GSC 2.2, Catalog**: 998,402,801 stars, >80 Megabytes, accessible over web from STScI
- **2MASS Point Source Catalog**: 470,992,970 stars, 32 Megabytes, ingest from 5 DVDs
- **USNO-A2.0 Catalog**: 526,280,881 stars, 6 Gigabytes, once available on 11 CDs

Astrometric Catalogs (with accurate proper motions)

- **UCAC2 Catalog**: 48,366,996 stars, 2 Gigabytes, install over web from CDS
- **Tycho-2 Catalog**: 2,539,913 stars, 529 Megabytes, available on CDROM or from CDS
Supported Catalogs

Photometric Catalogs (accurate photometry across catalog)

- **SDSS Photometry Catalog**: 53,000,000 sources, accessible over web from SDSS
- **2MASS Point Source Catalog**: 470,992,970 stars, 32 Megabytes, ingest from 5 DVDs
- **Tycho-2 Catalog**: 2,539,913 stars, 529 Megabytes, available on CDROM or from CDS

Wide Field Catalogs (reasonably complete at bright end)

- **HST Guide Star Catalog**: 25,541,952 sources, 1.2 Gigabytes, from 2 CDROMs
- **PPM Catalog**: 378,910 stars with proper motions, 22 Megabytes, available from SAO-TDC
- **SAO Catalog**: 258,996 stars with proper motions, 16 Megabytes, available from SAO-TDC
Catalog Search Options

Circle on the sky, center and radius specified

> scat -c ub1 -tn 10000 -r 900 10:00 85:00 J2000
Catalog Search Options

Square on the sky, center and half-side specified

> subl -tn 10000 -r -900 10:00 85:00 J2000
Catalog Search Options

Rectangle in coordinates, center and half-sides specified

> subl -tn 10000 -rr 900,900 10:00 85:00 J2000
Catalog Search Options

Image on sky using FITS WCS to specify region of coverage

> imub1 -n 30000 -q o -r 30 dss85.fits
makes a region file for ds9
Command Line Object Coordinates

• **Query either NED or SIMBAD**
  > nedpos m44
  08:40:22.198 +19:40:19.43
  > simpos m44
  08:40:24.000 +19:41:00.00 J2000

• **WCSTools coordinate conversion and formatting**
  > nedpos -g m44
  205.910635 +32.479519 Galactic
  > simpos -e m44
  127.346995 +1.291450 Ecliptic
Coordinate Manipulation

• **J2000 to Galactic**
  > skycoor -g 10:00 10:00 J2000
  227.54286  46.19107 galactic

• **J2000 to Ecliptic**
  > skycoor -e 10:00 10:00 J2000
  148.58768  -2.09451 ecliptic

• **J2000 to B1950**
  > skycoor -b 10:00 10:00 J2000

• **J2000 degrees to hours, minutes, seconds**
  > skycoor -j 150.0 10.0 J2000
  10:00:00.000 +10:00:00.00 J2000

• **Angular separation (in arcseconds)**
  > skycoor -r 10:00 10:00 09:57 10:14
  2787.590
Time Manipulation

• Current time to FITS ISO time
  > getdate now2fd
  2005-09-30T17:49:53.000

• Current time to Julian Date
  > getdate now2jd
  2453644.24304

• FITS ISO time to Julian Date
  > getdate fd2jd 2005-09-30T17:49:53.000
  2453644.24297

• FITS ISO time to Modified Julian Date
  > getdate fd2mjd 2005-09-30T17:49:53
  53643.74297
Image Rotation

An image can be rotated any multiple of 90 degrees and/or reflected about either axis.

> imrot -r 270 mc00380.fits
Image Extraction

A portion of a large FITS image can be extracted with an intact world coordinate system and a second WCS pointing to the original pixels.

```bash
> getfits mc00380r270w.fits `nedpos m44` 1000 1000
mc00380r270wa.fits
```
Image Extraction

The header of the extracted FITS file contains a world coordinate system which references any pixel to the corresponding pixel in the original image.

```
SIMPLE  =                    T
BITPIX  =                   16
NAXIS   =                    2
NAXIS1  =                 1000
NAXIS2  =                 1000
WCSNAMEP= 'PLATE   '
CTYPE1P = 'PIXEL   '
CRPIX1P =                -3798
CRVAL1P =                    1
CDELT1P =                    1
CTYPE2P = 'PIXEL   '
CRPIX2P =                -5651
CRVAL2P =                    1
CDELT2P =                    1
HISTORY  T2F 3.3.0 2004-06-24T17:18
HISTORY  Copy of image mc00380.fits
DATE-OBS= '1910-04-28T0:00'
CRVAL1 =        129.136370755
CRVAL2 =        19.772793105
WRA     = '08:35:52.657'
WDEC    = '+19:49:34.80'
WEPOCH  =                 2000
WEQUINOX=                 2000
RADECSYS= 'FK4     '
CRPIX1  =               910.54
CRPIX2  =               362.78
CTYPE1  = 'RA---TAN'
CRPIX1  =               910.54
CRPIX2  =               362.78
CD1_1   =      -0.000548642906
CD1_2   =      -0.000004732716
CD2_1   =      -0.000005340255
CD2_2   =       0.000548290586
WCSCAT= 'ppm     '
WCSCAT= 'mc00380r270.sex'
WCSCAT= 'ppm     '
WCSCAT= 'mc00380r270.sex'
WCSMATCH=                   90
WCSNREF =                  100
WCSTOL  =              10.0000
RA      = '08:36:32.729'
DEC     = '+19:46:22.06'
EQUINOX =                 1950
SECPX1 = 1.9752
SECPX2 = 1.9739
WCSSEP  =                3.945
EPOCH   =                 1950
HISTORY  GETFITS WCSTools 3.6.3 2005-09-30T17:24
```
### Image Distortion

A FITS-WCS standard for distortion is on its way, but in the mean time, the Spitzer Space Telescope needed to put distortion coefficients in image headers, so they used a snapshot of the developing standard.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTYPE1</td>
<td>'RA---TAN-SIP'</td>
<td>RA---TAN with distortion in pixel space</td>
</tr>
<tr>
<td>CTYPE2</td>
<td>'DEC--TAN-SIP'</td>
<td>DEC--TAN with distortion in pixel space</td>
</tr>
<tr>
<td>CPIX1</td>
<td>128.5000</td>
<td>Reference pixel along axis 1</td>
</tr>
<tr>
<td>CPIX2</td>
<td>128.5000</td>
<td>Reference pixel along axis 2</td>
</tr>
<tr>
<td>CRVAL1</td>
<td>324.025314317</td>
<td>[deg] RA at CRPIX1,CRPIX2 averaged over DCE</td>
</tr>
<tr>
<td>CRVAL2</td>
<td>56.870353364</td>
<td>[deg] DEC at CRPIX1,CRPIX2 averaged over DCE</td>
</tr>
<tr>
<td>CD1_1</td>
<td>0.000182402127</td>
<td></td>
</tr>
<tr>
<td>CD1_2</td>
<td>0.000286039417</td>
<td></td>
</tr>
<tr>
<td>CD2_1</td>
<td>0.000286039417</td>
<td></td>
</tr>
<tr>
<td>CD2_2</td>
<td>-0.000182402127</td>
<td></td>
</tr>
<tr>
<td>A_ORDER</td>
<td>2</td>
<td>polynomial order, axis 1, detector to sky</td>
</tr>
<tr>
<td>A_0_2</td>
<td>-1.263000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>A_1_1</td>
<td>-2.603000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>A_2_0</td>
<td>2.771000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>A_DMAX</td>
<td>0.684</td>
<td>[pixel] maximum correction</td>
</tr>
<tr>
<td>B_ORDER</td>
<td>2</td>
<td>polynomial order, axis 2, detector to sky</td>
</tr>
<tr>
<td>B_0_2</td>
<td>4.940000E-8</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>B_1_1</td>
<td>2.015000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>B_2_0</td>
<td>-4.806000E-6</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>B_DMAX</td>
<td>0.415</td>
<td>[pixel] maximum correction</td>
</tr>
<tr>
<td>AP_ORDER</td>
<td>2</td>
<td>polynomial order, axis 1, sky to detector</td>
</tr>
<tr>
<td>AP_0_1</td>
<td>-1.100000E-6</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>AP_0_2</td>
<td>1.263000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>AP_1_0</td>
<td>1.374000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>AP_1_1</td>
<td>2.603000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>AP_2_0</td>
<td>-2.771000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>BP_ORDER</td>
<td>2</td>
<td>polynomial order, axis 2, sky to detector</td>
</tr>
<tr>
<td>BP_0_1</td>
<td>4.199000E-6</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>BP_0_2</td>
<td>-4.947000E-8</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>BP_1_0</td>
<td>-5.882000E-6</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>BP_1_1</td>
<td>-2.015000E-5</td>
<td>distortion coefficient</td>
</tr>
<tr>
<td>BP_2_0</td>
<td>4.806000E-6</td>
<td>distortion coefficient</td>
</tr>
</tbody>
</table>
Remapping an Image

Pixels can be remapped from any projection WCSTools supports, including distortion, into a more standard projection such as plane tangent.
WCSTools Email Lists

WCSTools 4.0 is still being debugged.

To keep users informed about the status of the package, two email lists have been created:

- **wcstools-announce** will only announce software updates
- **wcstools** will allow users to help each other and let me know what features need more work or more documentation.

To subscribe, email *majordomo@cfa.harvard.edu* with one of the following in the body of the message:

- subscribe wcstools
- subscribe wcstools-announce
Doug's To Do Lists

Last year:

- **WCSTools**: Set up user mailing list
  Upgrade to WCSLIB 3.6
  Add XML/VOTable parser to catalog search
- **Archives**: Add last two years of FAST calibration data
  Start setting up access to data by program
- **VO**: Set up registry in a box for TDC archives

This year:

- **WCSTools**: Finish debugging version 4.0
  Sign up users for mailing list
- **Archives**: Write code to translate DEEP spectra format
  Put first 10 years of FAST spectra online
- **Scripting**: Learn Python and R
  Write WCSTools Python package
Astronomical Data Analysis Software & Systems XVI
October 15-18, 2006
Tucson, Arizona, USA