New Features in AST - a WCS Management and Manipulation Library

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Abstract.   Recent developments in the AST library are described, including a Python interface, support for the FITS-WCS "-TAB" system for storing tabular co-ordinate information, and extended support for representing distortions in spatial projections, using several schemes in common use (IRAF TNX/ZPX, Spitzer SIP, NOAO TPV and SCAMP).

1. PyAST - a Python wrapper for AST

The Starlink AST library provides a comprehensive range of facilities for attaching world co-ordinate systems to astronomical data, for retrieving and interpreting that information in a variety of formats, including FITS-WCS (Calabretta & Greisen 1999), and for generating graphical output based on it. It is a mature system that has been presented at several ADASS conferences over the past 14 years, ranging from Warren-Smith & Berry (1998) to Berry & Draper (2009). It is maintained by the Joint Astronomy Centre, Hawaii (`www.jach.hawaii.edu`) as part of the Starlink Software Collection (Jenness et al. 2009). For further information about AST, see the AST homepage at `www.starlink.ac.uk/ast`.

PyAST is a Python library that provides wrappers for the majority of functions provided by AST. It is publicly available and can be downloaded from github (`github.com/timj/starlink-pyasy/downloads`). Documentation is available at `dsberry.github.com/starlink/pyast.html`. PyAST requires Python 2.7 or later (version 3 is supported).

PyAST depends only on the numpy library (`numpy.scipy.org`). A copy of AST is bundled with PyAST, so no other parts of the Starlink Software Collection are required. Two optional interface are provided:

1. an interface for use with the AST Plot class that allows annotated axes to be drawn using the popular matplotlib graphics library (Barrett et al. 2005). This has many advantages over direct use of the axis annotation facilities provided by matplotlib itself. For instance, axis labels can be placed within the body of the plot, rather than round the edges (beneficial for many projections, and essential for all-sky projections). Also, AST can draw co-ordinate grids for projections that have peculiarities such as singularities and discontinuities.

2. an interface for use with the AST FitsChan class that allows AST to read and write FITS headers stored in a header object created by the PyFITS library (Barrett & Bridgman 1999).

PyAST provides a few high level functions that wrap up other PyAST calls to perform commonly required operations more easily. The HEALPix grid (Gorski et al. 2002) shown in figure 1. could be produced with code similar to the following:

```
>>> import pyfits
>>> import starlink.Atl as Atl
>>> import matplotlib.pyplot
>>>
>>> hdulist = pyfits.open( 'test.fit' )
>>> Atl.plotfitswcs( matplotlib.pyplot.figure().add_subplot(111),
>>>                   [ 0.1, 0.1, 0.9, 0.9 ], hdulist )
>>> matplotlib.pyplot.show()
```
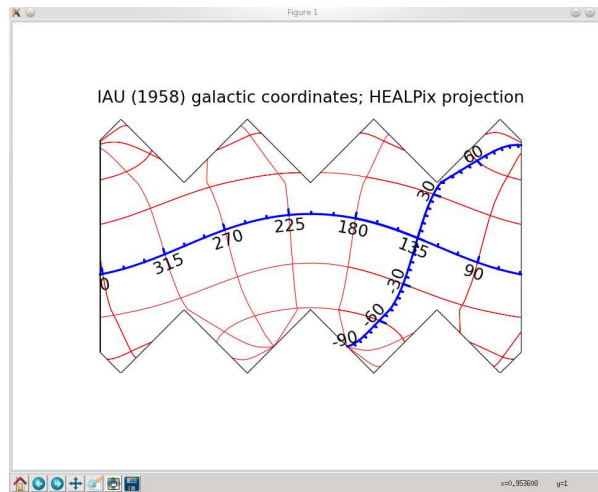

Figure 1.   PyAST displaying a HEALPix grid in a matplotlib window

2.   Support for Distorted Projections

When published, FITS-WCS paper IV will address the issue of the representation of distorted projections. But in the meantime, AST supports several of the interim schemes that are in common use, as listed below.

IRAF "-TNX": AST can now reads TNX projections described by Chebyshev or simple polynomial with half-cross terms.

IRAF "-ZPX": AST can now reads ZPX projections described by Chebyshev or simple polynomial with half-cross terms.

Spitzer "-SIP": AST has been able to read SIP projections (Shupe et al. 2005) for some time, but SIP support has been improved recently. Within a SIP header, the forward and inverse transformations between world and pixel co-ordinates are defined by separate polynomials, but some SIP headers do not define an inverse transformation (from world to pixel co-ordinates). For such a header, AST can now implement an iterative inverse transformation.

IRAF "-TPV": AST now supports this renaming of the distorted TAN projection included in an early draft of FITS-WCS paper II.

SCAMP "-TAN": This is the same as the TPV projection, but uses a CTYPE code of "-TAN" instead of "-TPV". AST differentiates between SCAMP (Bertin 2006) TAN headers and standard TAN headers by looking for PV keywords attached to the latitude axis (a standard TAN projection should have no such latitude PV keywords).

AUTOASTROM "-TAN": This is another representation of the TPV projection, again using a CTYPE code of "-TAN", but using QV keywords instead of PV keywords to store the polynomial coefficients.

3. DS9 and AST

AST was written to provide co-ordinate handling facilities for the Starlink software collection, including GAIA, SPLAT, KAPPA, *etc.*, but it is now also used in other non-Starlink software. Particularly, the DS9 image browser (Joye 2011) has for many years used AST to draw its annotated co-ordinate grids. As of DS9 version 7.0 (currently in beta testing), it will use AST additionally for all its WCS transformations, thus benefiting from the improvements to support for distorted projections listed above.

4. Support for the FITS-WCS "-TAB" Algorithm

AST now includes support for reading and writing tabular WCS information in the form of FITS headers using the "-TAB" algorithm described in FITS-WCS paper III. Currently, no support is included for the multi-dimensional tables needed to describe non-separable axes.

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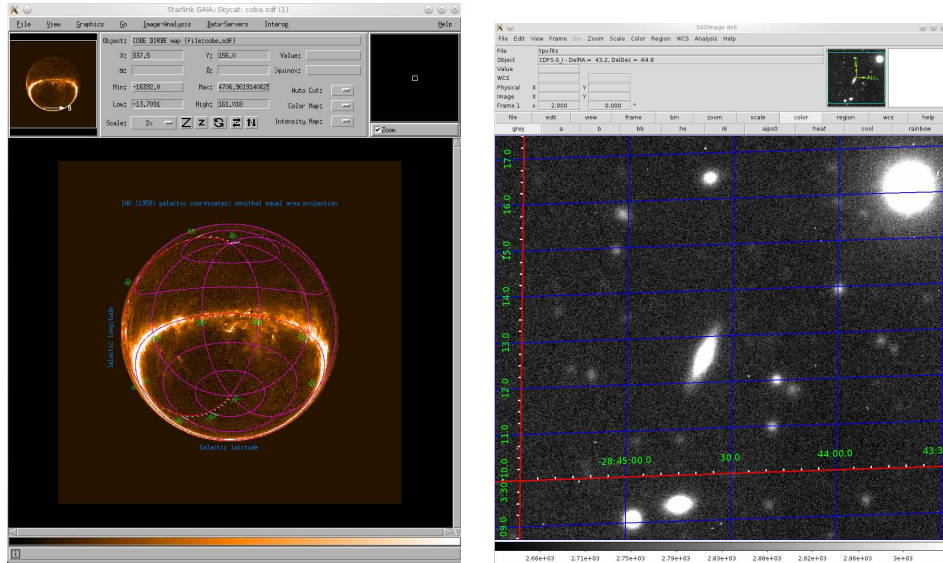
Figure 2.   Left: GAIA using AST to display a co-ordinate grid for a ZEA (zenithal equal area) projection. Right:DS9 using AST to display a co-ordinate grid for a TPV (distorted TAN) projection.

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