



STScI | SPACE TELESCOPE
SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

GWCS – A General Approach to World Coordinates

Nadia Dencheva and Perry Greenfield

ADASS XXVIII, Nov 12, 2018



What is GWCS?

- GWCS is an astropy affiliated package written in python.
- It addresses the problem of expressing transformations between coordinate systems in a general way.
- In this context the term “WCS” encapsulates the entire transformation pipeline from input coordinates to world coordinates.
- The WCS is serialized using the Advanced Scientific Data Format (ASDF).



Motivation

- Chain an arbitrary number of distortion corrections.
- Represent and use arbitrary types of transforms.
- Represent discontinuous WCSs (IFU, MOS)
- Use non-coordinate inputs as arguments to the transforms.
- Save astrometric information with the data.



Data Model

GWCS supports a data model which includes the entire transformation pipeline from input coordinates (detector by default) to world coordinates. The pipeline is represented as a list of steps executed in order.

```
>>> pipeline = [(detector_frame, distortion),  
...             (undistorted_frame, det2sky),  
...             (sky_frame, None)  
...            ]
```




Coordinate Frames in GWCS

- Coordinate frames are mostly info containers, with attributes such as ``axes_names``, ``axes_type``, ``axes_order``, ``axes_physical_type``, ``unit``.
- They provide a method to transform numerical results into astropy objects using the attributes of the frame.
- The output coordinates are rich astropy objects which can be further transformed using astropy methods.



Supported Coordinate Frames

- Celestial coordinates are instances of `astropy.SkyCoord` and are transformed to other standard celestial frames using `astropy.coordinates`.
- Time coordinates are represented by `astropy.Time`.
- Spectral coordinates are `astropy.Quantity` objects and can be converted to other units using the tools in `astropy.units`.
- Cartesian coordinates use `astropy.units`.
- Custom frames can be constructed by specifying the attributes.



Transforms in GWCS

- Transforms are instances of `astropy.Model` and use the flexible framework of compound models in `astropy.modeling`.
- Transforms can be chained, joined or combined using Python-enabled operators.
- They can be initialized and evaluated with quantities.
- Many commonly used models are already implemented in `astropy.modeling`.



GWCS Features

- Validation of the overall structure, the coordinate frames and transforms
- Include intermediate coordinate frames in the WCS pipeline
- Retrieve or update a transform between any two coordinate frames
- A new tool in GWCS takes two matching sets of points in detector and sky coordinates and creates a WCS object

```
>>> wcsobj = wcs_from_points(xy, radec)
```




GWCS Features, cont'd

GWCS supports the **Shared WCS API** defined in

<https://doi.org/10.5281/zenodo.1188874>

- The API is designed to expose the basic WCS functionality in a way agnostic to the WCS representation.

```
>>> wcsobj.pixel_to_world  
>>> wcsobj.world_to_pixel
```

- It sets a common understanding of how to convey information about the physical type and representation of a world coordinate in Python.



WCS Serialization

GWCS utilizes the Advanced Scientific Data Format, [ASDF Standard](#), and its Python implementation, [asdf](#), to serialize and validate GWCS objects.

There are two ways to save a WCS to a file

- ASDF file
- ASDF extension to a FITS file



WCS Serialization, cont'd

- ASDF makes use of abstract data type objects called schemas.
- Serializations happens in classes referred to as tags.
- ASDF files are yaml files with numerical arrays saved as binary blocks.
- ASDF utilizes jsonschema to validate the structure of objects and their metadata.



WCS Serialization, cont'd

- The validation happens transparently to the end user. In general one does not need to know anything about schemas and yaml in order to use or construct a WCS object.
- Packages using GWCS may create their own transforms and schemas and register them as an `Asdf Extension`



Who Uses GWCS

- The JWST project
 - Imaging
 - Spectral slit
 - IFU
 - MOS
 - Grism
- DKIST
 - WCS of a high dimensional representation of many FITS files



Useful Links

GWCS is developed on Github.
Contributions to code and documentation are welcome.

- <https://github.com/spacetelescope/gwcs>
- <https://gwcs.readthedocs.io/en/latest/>
- <https://asdf-standard.readthedocs.io/en/latest/>
- <https://asdf.readthedocs.io/en/latest/>
- <https://astropy.org>
- APE 14 - A Shared WCS API
https://zenodo.org/record/1188875#.W-LPQIInb_Q