Proposal for Astronomical Outreach Imagery Metadata Tags for the Virtual Observatory Version 1.1[1]

Robert Hurt
Lars Lindberg Christensen
with input from the
Metadata Sub-group of the IAU Virtual Repository Programme Group

Abstract

We here propose a standard for Astronomical Outreach Imagery (AOI) metadata that can span both "photographic" images produced from science data and "artwork" illustrations. This standard will allow individual image files to be catalogued and offered through searchable databases like the Virtual Observatory (VO).

The proposed standard includes both the metadata schema for describing outreach images and the method by which the metadata may be embedded within the image file. Embedded metadata are commonly in use in digital photography and the publication industry, and the standard proposed here will easily integrate into those workflows. For data-derived images, full World Coordinate System (WCS) tags can be used to describe fully the position, orientation, and scale of the image while allowing for a variety of applications requiring the full coordinate context.

---

[1]Submitted to the Registry Working Group of the IVOA, registry@ivoa.net 27. March 2006.

Overview

This document outlines a proposal to the Registry Working Group of the International Virtual Observatory Alliance (IVOA, registry@ivoa.net) for metadata tags that cover the requirements for Astronomical Outreach Imagery (dubbed AOI in this document). This metadata schema has been developed within the framework of the IAU Virtual Repository project[2].

Intended Scope of AOI Metadata Schema

The astronomical education and public outreach (EPO) community plays a key role in conveying the results of scientific research to the general public. A key product of EPO development is a variety of non-scientific public image resources, both derived from scientific observations and created as artistic visualizations of scientific results. This refers to general image formats such as JPEG, TIFF, PNG, GIF, *not* scientific FITS datasets. Such resources are currently scattered across the internet in a variety of galleries and archives, but are not searchable in any coherent or unified way.

Just as Virtual Observatory (VO) standards open up all data archives to a common query engine, the EPO community would benefit greatly from a similar mechanism for image search and retrieval. Existing metadata standards for the Virtual Observatory are tailored to the management of research datasets and only cover EPO resources (like publication quality imagery) at the "collection" level and are thus insufficient for the needs of the EPO community.

The primary focus of this document is on print-ready astronomical imagery, which has been rendered from telescopic observations (also known as "pretty pictures"). Such images can combine data acquired at different wavebands and from different observatories. While the primary intent is to cover data-derived astronomical images, there are broader uses as well. Specifically, the most general subset of this schema is also appropriate for describing artwork and illustrations of astronomical subject matter. This will be covered in some detail in later sections.

This AOI schema is intended only for single images of specific astronomical subject matter. Image resources not covered in this schema include: collages of multiple images, diagrams and illustrations of more general physics phenomena and animations or videos.

The AOI tags defined by this document reflect the *minimal set* necessary for fully describing the image creator, subject matter, data sources, overall interpretation and usage rights.

The intended users of these datasets cover a broad variety of fields: educators, students, journalists, enthusiasts, and scientists. The core set of required tags define the key elements needed in a practical database for identification of desired resources. For example, one might choose to search for images of the Crab Nebula that include both X-

---

[2] For more info see http://www.communicatingastronomy.org/repository

ray and visible light elements, or for any images within 2 degrees of a specified location on the sky that include at least some data from the Spitzer Space Telescope.

Because of this broad user base, the choice of tags is intended to reflect general needs and does not include application-specific content (for instance "grade level"). Users with more specific needs may subsequently employ these tags within a subset of a more extensive schema developed for the purpose.

Metadata Portability

Beyond the core definitions of the metadata tags, the AOI standard also defines that the metadata are embedded within the image files.

We have chosen the Adobe© Extensible Metadata Platform (XMP) specification as the basis for embedding AOI metadata. XMP tags are stored within the image header of all common image formats and can be read by popular image processing and cataloguing packages. The XMP standard is also widely used by photographers and the publication industry. Anyone familiar with consumer and professional digital cameras may already be familiar with Exchangeable image file format (EXIF) metadata tags that include camera and exposure information within the digital photo file as a set of XMP tags.

The advantages of embedded image identity metadata are numerous. It effectively makes the images self-documenting, which is particularly useful when the source URL for an image is lost. Moreover, it would be possible for an image server to catalog its resources on the fly by reading the metadata from existing files. One could also imagine an "Astro-Google" web search engine that could search out any image on the web tagged with AOI metadata and offer the links via an astronomically-tailored search interface.

In principle, any such tagged image resource should be searchable and indexed regardless of where it is actually hosted or provided from. This standard is intended to open up the opportunities for publication to a much larger degree than possible today. One could imagine a small observatory or an amateur astronomer possessing only the resources to establish an online gallery, but allowing its contents to be searched by an external data-mining package. Or the image files could be uploaded to a curated site that itself might interface with the VO.

Referenced Standards

The schema proposed here have been developed within several existing standards. These include the Virtual Observatory (VO), the International Press Telecommunications Council (IPTC), and the Adobe© Extensible Metadata Platform (XMP).

The IVOA document "Resource Metadata for the Virtual Observatory Version 1.1[3]" provided a base for developing the AOI metadata standard. Naming conventions for AOI tags are derived from VO equivalents where possible. However, these VO tags were developed primarily to describe entire resource collections, not something as fine-grained as individual images. Thus many additional tags have been added beyond the VO base.

---

[3] Resource Metadata for the Virtual Observatory: http://www.ivoa.net/Documents/latest/RM.html

These new and expanded tags are proposed to the VO standards board for eventual inclusion in the VO standards.

The specifications for the World Coordinate System (WCS) descriptors were drawn directly from the IVOA "Simple Image Access Specification Version 1.0[4]." This allows for possible interoperability with other systems based on this specification.

The methods for embedding metadata directly within the image files are described within the Adobe© XMP specification[5]. This provides an XML system for encoding the data, methods for directly editing the tags within Adobe© Photoshop, as well as a developer's Software Development Kit for developing custom software applications to read the embedded tags. Many content management systems and image catalog programs already support XMP tags and will be capable of reading at least the AOI tags mapped into IPTC slots.

The IPTC has developed an extensive XMP metadata schema[6] to cover the needs of the publication industry. These tags are designed to provide full content description including contact information for the creator of the image. As such they are closely aligned with the AOI requirement for image content description. Therefore the AOI tags have been mapped into existing IPTC fields, where available. This has the added benefit of assisting with image publication in printed media, since many of the IPTC tags used in this process will already be populated with information from the AOI standard.

World Coordinate System Notes

The AOI metadata standard allows for the inclusion of full World Coordinate System (WCS) tags that fully describe the image location, scale, and orientation on the sky. The advantages of a fully-tagged dataset are potentially enormous. They may be located in position-based queries like any full scientific dataset. In addition, it is possible for users to develop software to allow for automatic image registration and alignment; for instance for automatic inclusion in digital planetarium projections.

A new software tool under development at the Space Telescope Science Institute (STScI) can facilitate the inclusion of coordinate data in image headers. The WCS Transfer Tool (under development by Frank Summers, Lisa Frattare, and Zolt Levay) uses calibrated astronomical images to calculate WCS data for astronomical outreach images. The STScI project is actively working with the AOI metadata project described in this document to correlate efforts to matching specifications.

FITS Liberator Notes

This document is needs-driven in the sense that it contains the tags and object taxonomy that were implemented with the ESA/ESO/NASA Photoshop FITS Liberator[7] Version 2.1, released in March 2006. The FITS Liberator is being developed as one convenient tool for the creation of publication-ready imagery by importing astronomical FITS image

---

[4] Simple Image Access Specification: http://www.ivoa.net/Documents/latest/SIA.html
[5] Adobe XMP: http://www.adobe.com/products/xmp/overview.html
[6] IPTC Metadata for XMP: http://www.iptc.org/IPTC4XMP/
[7] FITS Liberator: http://www.spacetelescope.org/projects/fits_liberator

files into Photoshop. It inserts the AOI tags described in this document in the same step, and can even populate some of the fields from information in the FITS files.

Information on the XMP implementation for the FITS Liberator may be found in a separate document[8].

---

[8] Liberator Metadata Serialization: http://www.spacetelescope.org/projects/fits_liberator/xmp.pdf

AOI Metadata Tag Descriptions

Tag Formats

Each of the metadata tags has one of several possible formats summarized below.

- String – a free-format text field composed of Unicode Characters[9]. UTF-8 shall be supported as ASCII-preserving encoding method for Unicode.

- String-CV – an ASCII string from a given choice of predefined values taken from a "controlled vocabulary".

- Float – an ANSI/IEEE-754 single precision floating point number. The ASCII representation starts with an optional "-" "+", followed by the positive decimal number whereby the fractional part is following a dot ".". The base is followed by the ASCII letter "E" or "e". The base-10 exponent is made of an optional "-" or "+" followed by 1 or 2 digits. The special value "NaN" is accepted for missing values.

- URL – universal resource locator, a standard web address following the IETF standard[10].

- URI – universal resource identifier according to the IETF standard[11]; when used to reference a VO resource then the conventions defined in the proposed recommendation "IVOA Identifiers"[12] apply.

All "controlled vocabulary" lists for tags may be found in Appendix A.

Tags are considered to be single-valued unless specified to be a "list" that can contain multiple elements. The delimiter for list elements is the semicolon ";". Lists can come in several formats:

- List – can have any number of elements

- List(n) – has exactly n elements

- List-ordered – a multi-element list where order is correlated between tags

Note that the "list-ordered" property is specifically defined to describe the color channels in a composite image compiled from multiple astronomical datasets. For instance, in the case of a 3-channel RGB image created from different source FITS files, each tag that is

---

[9] Unicode Consortium, The Unicode Standard V4.0, 2003, http://www.unicode.org/standard/standard.html
[10] Berners-Lee et al. 1994, Uniform Resource Locators (URL), IETF RFC 1738, http://www.ietf.org/rfc/rfc1738.txt
[11] Berners-Lee et al. 1998, Uniform Resource Identifiers (URI): Generic Syntax, IETF RFC 2396, http://www.ietf.org/rfc/rfc2396.txt
[12] Plante et al., 2005, IVOA Identifiers V1.10, http://www.ivoa.net/Documents/latest/IDs.html

list-ordered would contain the information for each FITS file in the same sequential order.

Levels of Requirement

To form a meaningful database for user searches, certain minimum sets of AOI metadata tags must be supplied. However, subsets of these tags may be identified as necessary for specific purposes, though each image resource need not supply all possible tags. The requirement levels define the minimum set of tags to render a resource valid for each purpose.

- All – these are the minimum set required for any purpose including illustrations

- Image – required for any image derived from data

- WCS-base – these are the minimum descriptors needed for a basic position search

- WCS-full – these define the full geometric projection and location of an image

- Server – these are required for a "curator site" or for a central registry (like the VO)

The WCS-base set assumes only rudimentary positional information (a coordinate that falls somewhere within the image, but lacking scale or projection). It is still sufficient for simple positional cone searches.

The "server" tags are only applicable with respect to a specific registry. They are not currently meaningful, but are left as placeholders for search services, as they emerge, that might require this information.

Example Metadata

This table provides an example of a filled-out AOI metadata tag set. Full explanations of individual fields are given in the following section.

Tag Name	Format	List	Example	IPTC Equivalent	Path	Required
Version Metadata						
1. AOI MetadataVersion	string		1.1			all
Creator Metadata						
2. Creator	string		Spitzer Science Center	Source	photoshop:Source	all
3. CreatorURL	URL		http://www.spitzer.caltech.edu	CiUrlWork		
4. Contact.Name	string	list	Gordon Squires	Creator	photoshop:Authors	
5. Contact.Email	string	list	squires@ipac.caltech.edu	CiEmailWork	CreatorContactInfo/Iptc4xmpCore:CiEmailWork	
6. Contact.Telephone	string	list	888-555-1212	CiTelWork	CreatorContactInfo/Iptc4xmpCore:CiTelWork	
7. Contact.Address	string		1200 E. California Blvd.	CiAdrExtadr	CreatorContactInfo/Iptc4xmpCore:CiAdrExtadr	
8. Contact.City	string		Pasadena	CiAdrCity	photoshop:City	
9. Contact.StateProvince	string		CA	CiAdrRegion	photoshop:State	
10. Contact.PostalCode	string		90066	CiAdrPcode	CreatorContactInfo/Iptc4xmpCore:CiAdrPcode	
11. Contact.Country	string		USA	CiAdrCtry	CreatorContactInfo/Iptc4xmpCore:CiAdrCtry	
12. Rights	string		Public domain, no restrictions on use	RightsUsageTerms	xmpRights:UsageTerms	all
Content Metadata						
13. Headline	string		Majestic Sombrero Galaxy	Headline	photoshop:Headline	all
14. Subject.Category	string-CV	list	Galaxy:[Type]:Elliptical	Category	photoshop:Category	all
15. Subject.Name	string	list	Sombrero Galaxy; M 104; NGC 4594	Keywords	photoshop:SupplementalCategory	
16. Description	string		This combined image from Hubble and Spitzer shows the distinctive dust ring inside this elliptical galaxy.	Description	photoshop:Description	
17. ReferenceURL	URL		http://www.spitzer.caltech.edu/Media/releases/ssc2005-11/			
18. Credit	string		NASA/JPL-Caltech/R. Kennicutt (University of Arizona) & the SINGS Team and NASA/Hubble Space Telescope/Hubble Heritage Team	Provider	photoshop:Credit	all
19. Date	string		2005-04-05	Date Created	photoshop:DateCreated	all
20. ID	string		ssc2005-11a			
21. Type	string-CV		Photographic			all
Observation Metadata						
22. Facility	string	list-ordered	Hubble Space Telescope; Spitzer Space Telescope; Spitzer Space Telescope			image
23. Instrument	string	list-ordered	ACS; IRAC: IRAC			
24. Spectral.ColorAssignment	string-CV	list-ordered	Blue; Green; Red			image
25. Spectral.Band	string-CV	list-ordered	Visible; Infrared; Infrared			image

26. Spectral.Bandpass	string	list-ordered	B; near infrared; [OIII]			
27. Spectral.CentralWavelength	float	list-ordered	550; 3500; 8000			
28. Spectral.Notes	string		Composite from Hubble Heritage image and Spitzer observations			
29. Temporal.StartTime	float	list-ordered	2003-05-01-1243; 2005-05-04-0945; 2005-05-04-2212			
30. Temporal.IntegrationTime	float	list-ordered	200; 240; 240			
31. DatasetID	URI	list-ordered	ivo://NASA.HST/U2JZ0607 B; n/a; n/a			
32. Spatial.CoordinateFrame	string-CV		FK5			WCS-base
33. Spatial.Equinox	string		J2000			WCS-base
34. Spatial.ReferenceValue	float	list(2)	27.32342;66.092421			WCS-base
35. Spatial.ReferenceDimension	float	list(2)	3000; 1681			WCS-full
36. Spatial.ReferencePixel	float	list(2)	1500.5; 840.5			WCS-full
37. Spatial.Scale	float	list(2)	-5.555e-5; 5.555e-5			WCS-full
38. Spatial.Rotation	float		-12.2			WCS-full
39. Spatial.CoordsystemProjection	string-CV		TAN			WCS-full
40. Spatial.CDMatrix	float	list(4)	'-5.555e-5; 0.0; 0.0; 5.555e-5			
41. Spatial.Quality	string-CV		Full			WCS-base
42. Spatial.Notes	string		coordinates reconstructed using WCS Tool			
43. ImageProductQuality	string-CV		Good			
Publisher Metadata						
44. Publisher	string		Infrared Science Archive			server
45. PublisherID	URI		ivo://IRSA.IPAC			server
46. ResourceID	URI	list	ivo://IRSA.IPAC/spitzer.ssc2005-11a			server
File Metadata						
47. File.Type	string-CV		TIFF			all
48. File.Dimension	float	list(2)	3000; 1681			all
49. File.Size	float		6251			all
50. File.BitDepth	float		24			all
Metadata Extension: FITS Liberator						
51. FL.StretchFunction	string-CV	list-ordered	linear; log; log			
52. FL.BackgroundLevel	float	list-ordered	n/a; 2.5; 5.7			
53. FL.PeakLevel	float	list-ordered	n/a; 256; 182			
54. FL.ScaledBackgroundLevel	float	list-ordered	n/a; 0; 0			
55. FL.ScaledPeakLevel	float	list-ordered	n/a; 100; 100			
56. FL.BlackLevel	float	list-ordered	n/a; 0; 0			
57. FL.WhiteLevel	float	list-ordered	n/a; 2; 2			
58. FL.CreationNotes	string		FITS data for Spitzer combined with published Hubble TIFF file			

Metadata Definitions

The meaning of each metadata tag is specified in the following list. The format of the tag is indicated in parenthesis, and the requirement level is indicated at the end. Equivalent IPTC tag mappings are indicated under comments.

Version Metadata

1. AOIMetadataVersion (string)   new. all

Definition: This is the version of the applied Metadata definition (as per this document).

Creator Metadata

These tags identify the source of the resources and would likely not change much from product to product.

2. Creator (string)   all

Definition: Original Creator of the resource.

Comment: Examples of a Creator include a person or an organization. IPTC equivalent: Source.

3. CreatorURL (URL)   new

Definition: A simple URL pointing to the (top level) (outreach) webpage for the original creator.

Comment: IPTC equivalent: CiUrlWork

4. Contact.Name (string, list)

Definition: Name(s) of the primary contact(s) for the resource.

Comment: IPTC equivalent: Creator

5. Contact.Email (string, list)

Definition: Email(s) of the primary contact(s) for the resource.

Comment: In some cases, a contact may have a more reliable long-term email address than URL, so this could be a useful optional tag. IPTC equivalent: CiEmailWork

6. Contact.Telephone (string, list)

Definition: Telephone number(s) of the primary contact for the resource.

Comment: IPTC equivalent: CiTelWork

7. Contact.Address (string)

Definition: Street address of the primary contact for the resource.

Comment: IPTC equivalent: CiAdrExtadr

8. Contact.City (string)

Definition: City of the primary contact for the resource.

Comment: IPTC equivalent: CiAdrCity

9. Contact.StateProvince (string)

Definition: State or province of the primary contact for the resource.

Comment: IPTC equivalent: CiAdrRegion

10. Contact.PostalCode (string)

Definition: Zip or postal code of the primary contact for the resource.

Comment: IPTC equivalent: CiAdrPcode

11. Contact.Country (string)

Definition: Country of the primary contact for the resource.

Comment: IPTC equivalent: CiAdrCtry

12. Rights (string)   *all*

Definition: Copyright and related intellectual property rights description.

Comment: IPTC equivalent: RightsUsageTerms

Content Metadata

13. Headline (string)   *all*

Definition: General descriptive title given to the image resource.

Comment: IPTC equivalent: Headline

14. Subject.Category (string-CV, list)   *all*

Definition: The type(s) of object or objects in the resource; this should be chosen from a pre-defined list.

Comment: The list of choices is offered in Appendix A. IPTC equivalent: Category

15. Subject.Name (string, list)

Definition: Proper names/catalog numbers for all of the key objects in the image field.

Comment: This should include any common or proper names (e.g. Mars; Whirlpool Galaxy; Orion Nebula) as well as common catalog identifiers. For deep-sky objects this should include Messier and NGC numbers (when available), or other common catalog identifiers (e.g. M 82; NGC 7337; IC 342). If possible such identifiers should be obtained from services like Simbad or NED (for extragalactic objects). IPTC equivalent: Keywords

16. Description (string)

Definition: Full caption and related description text for the image resource.

Comment: IPTC equivalent: Description

17. ReferenceURL (URL)

Definition: Webpage containing more information about this specific image.

18. Credit (string)   *all*

Definition: The minimum information that the Publisher would like to see mentioned when the resource is used.

Comment: It is mandatory for users of the resource to mention the Credit in the end-product. See also Rights. IPTC equivalent: Provider

19. Date (string)   *all*

Definition: Date that the resource was created or made available. (YYYY-MM-DD).

Comment: Also known in daily use as release date (note that this is distinct from the observation date, see field 33 below). IPTC equivalent: DateCreated

20. ID (string)

Definition: This is an identifier for the resource that is unique to the creator.

Comment: This is typically some variation of a sequence number or date-derived tag; for example it could be the press release ID.

21. Type (string-CV)   *all*

Definition: The type of resource.

Comment: For all astronomical publication images, this should by default be set to "Photographic". Perhaps the VO definition of type should be expanded to include different EPO types such as 3D models, videos etc. The list of existing types in the VO is given in Appendix A.

Observation Metadata

The information in this section characterizes the observational data of source datasets used to create the publication-quality image. These include the data sources (facility, instruments, etc), the geometric projection on the sky, and the wavelength/color assignments used for composite images.

Much of this data can be derived from information in the FITS headers of the source data. However, if multiple datasets are combined for a color image, each of the list-ordered tags must have the information for each color channel assigned in the correct order. For instance, for a simple 3-channel RGB image, the Spectral.ColorAssignment tag may be

set to "Red; Green; Blue" and subsequent list-ordered tags should identify the contents of the red, green, and blue channels respectively.

Note that if WCS coordinate data is extracted directly from the FITS header, the solution will have to be re-derived if the image is cropped and/or rotated.

If the image is resized after the WCS solution is derived (but without further cropping/rotation), the projection solution is still valid, though the Spatial.Scale, Spatial.ReferencePixel, and Spatial.CDMatrix will no longer correspond directly to the image. These values may be rescaled using the ratio of Spatial.ReferenceDimension (the image dimension for which the WCS solution is valid) and File.Dimension (the actual dimensions of the image). This situation can occur if the original source image is resized and saved with the existing AOI metadata intact.

22. Facility (string, list-ordered)   image

Definition: Telescopes or observatories used for the observations.

Comment: For this keyword, the list should reference facilities in order of the elements in the composite image.

23. Instrument (string, list-ordered)

Definition: Instrument used to collect the data. One Instrument per exposure.

Comment: For this keyword, the list should reference instruments in order of the elements in the composite image.

24. Spectral.ColorAssignment (string-CV, list-ordered)   image

Definition: The output color that is assigned to an exposure. One ColorAssignment per exposure. ColorAssignment should be chosen from a controlled vocabulary list.

Comment: Options include Blue, Orange etc. Consult Appendix A for specific options for this tag.

25. Spectral.Band (string-CV, list-ordered)   image

Definition: Waveband of the component exposure from a pre-defined list defining the general part of the spectrum covered. One Spectral.Band per exposure.

Comment: The elements in the list should be in the same ordering as for Facility and Instrument above to specifically identify each contributing image in a color composite. This list specifically includes text descriptors of the band such as e.g. Radio, Optical, Gamma-ray etc. Consult Appendix A for specific options for this tag.

26. Spectral.Bandpass (string, list-ordered)

Definition: Bandpass of the individual exposure. One Coverage.Spectral.Bandpass per exposure.

Comment: This free-form string allows the spectral coverage to be identified more precisely. Ideally this should refer to commonly used bandpasses (e.g. B, V, R, I, J, H, K,

etc.), specific line excitations or transitions (Halpha, SIII, CO(3-2), etc.), or if appropriate, instrument specific channels or filters (only if no other descriptor is adequate).

27. Spectral.CentralWavelength (float, list-ordered)

Definition: Central wavelength of the filter used for the individual exposure measured in nanometers. One Coverage.Spectral.CentralWavelength per exposure.

28. Spectral.Notes (string)

Definition: Free-text field to allow for more detailed discussions of bandpasses and color mappings.

29. Temporal.StartTime (string, list-ordered)

Definition: Start time of the exposure in format YYYY-MM-DD-HHMM [UT]. One Coverage.Temporal.StartTime per exposure.

Comment: This field would be populated from the FITS keyword DATE-OBS.

30. Temporal.IntegrationTime (float, list-ordered)

Definition: The exposure time in seconds. One Temporal.IntegrationTime per exposure.

Comment: This is usually a more interesting quantity for general purposes than specific stop time, and more meaningful if the start time is only known approximately. This field would be populated from the FITS keyword EXPTIME.

31. DatasetID (URI, list-ordered)

Definition: VO-compliant reference to the dataset (the exposure) used to construct the final image (if available). The format is [ivo://AuthorityID/ResourceKey]. One DatasetID per exposure.

32. Spatial.CoordinateFrame (string-CV)   *WCS-base*

Definition: Coordinate system reference frame. Coverage.Spatial.CoordinateFrame should be chosen from a pre-defined list.

Comment: This field would be populated from the FITS keyword: CFRAME. Options include FK5, GAL etc. Consult Appendix A for specific options for this tag.

33. Spatial.Equinox (string)   *WCS-base*

Definition: Equinox for Coverage.Spatial.CoordinateFrame.

Comment: This field would be populated from the FITS keyword: Equinox. It usually defaults to J2000, except that the default for FK4 is B1950.

34. Spatial.ReferenceValue (float, list(2))   *WCS-base*

Definition: Reference coordinates for the image (2 element list in decimal degrees).

Comment: This and subsequent Coverage.Spatial tags deviate from existing VO standards for sky coordinates to more closely follow standards for FITS Keywords. This field would be populated from the FITS keywords: CRVAL1, 2.

35. Spatial.ReferenceDimension (float, list(2))   WCS-full

Definition: Size of the image in pixels (2 element list).

Comment: FITS Keywords: NAXIS1,2 (also equivalent to image dimensions).

36. Spatial.ReferencePixel (float, list(2))   WCS-full

Definition: X,Y coordinates of the pixel in the image to which the reference coordinate (Coverage.Spatial.ReferenceValue) refers (2 element list).

Comment: FITS Keywords: CRPIX1,2; In many common FITS files the reference pixel is not the centre pixel in the image.

37. Spatial.Scale (float, list(2))   WCS-full

Definition: Spatial scale of the image in number of degrees/pixel (2 element list).

Comment: FITS Keywords: CDELT1, CDELT2 (or derived from CD matrix). Is required for Simple Image Access operation (as per SIA Specification v. 1.0).

38. Spatial.Rotation (float)   WCS-full

Definition: Position angle of the Y axis in degrees measured east from north.

Comment: FITS Keywords: CROTA1,2 (the FITS standard allows for two values, but typically only one is used). Sky rotation is measured east from north which, for astronomical images, is counter-clockwise (east and west are reversed in a sky projection compared to a map projection). Is required for Simple Image Access operation (as per SIA Specification v. 1.0).

39. Spatial.CoordsystemProjection (string-CV)   WCS-full

Definition: A combination of the coordinate system and the projection of the image.

Comment: Typical projections include "TAN", "SIN", "CAR" (Cartesian flat projection) and "AIT" (AITOFF equal-area all-sky), among others. This keyword is derived from the contents of the standard FITS Keywords: CTYPE1,2. Consult Appendix A for specific options for this tag.

40. Spatial.CDMatrix (float, list(4))

Definition: Four matrix describing elements concerning pixel scale, rotation and skew.

Comment: FITS Keywords: CD1_1, CD1_2, CD2_1 and CD2_2 (or derived from Coverage.Spatial.Scale and Coverage.Spatial.Rotation). Not required, but encouraged for Simple Image Access operation (as per SIA Specification v. 1.0).

41. Spatial.Quality (string-CV)   *WCS-base*

Definition: This qualitatively describes the reliability of the spatial coordinate information in this metadata. Coverage.Spatial.Quality should be chosen from a pre-defined list.

Comment: This value needs to be set by the user. Values include:

- **Full** – Verified full WCS information (though may exclude CD matrix)
- **Position** – Spatial.ReferenceValue describes a coordinate contained somewhere within the image; other WCS info is approximate or unreliable
- **Unknown** – missing or unverified/unreliable

See Appendix A for full listing.

42. Spatial.Notes (string)

Definition: Free-text description to expand further on coordinates/geometry of image.

Comment: This field can be used to include human-friendly descriptions of the image geometry (e.g. "RA=2h23m15.2s, Dec=-25d15m22s, field of view = 22 x 15 arcmin, north is 37 degrees clockwise from up").

43. Image.ProductQuality (string-CV)

Definition: Qualitative image quality assessment. ProductQuality should be chosen from a pre-defined list.

Comment: The existing data quality assessment in the VO is not defined appropriately for PR resources. Possible choices are:

- **Good** – Clean, publication-ready image
- **Moderate** – Some flaws in the image, but of good quality
- **Poor** – Degraded quality; significant artefacts, but still acceptable for reference

See Appendix A for full listing.

Publisher Metadata

44. Publisher (string)   *server*
Definition: Publisher of the resource.

Comment: Examples of a Publisher include a person or an organization.

45. PublisherID (URI)   *server*
Definition: ID of publisher registered as VR providers.

Comment: For instance a simple sign-up sheet on a central server. PublisherID is required if the data should be part of the VR.

46. *ResourceID (URI, list)*   *server*

Definition: Identifier for the resource (VO-compliant URI, Universal Resource Identifier).

Comment: May optionally be a list if more than one publisher releases the same image. All identifiers should be included if possible. Any organization or individual should be entitled to obtain an URI from a central organization.

File Metadata [implicit]

These metadata fields are not stored as editable values like the other AOI tags, but are implicit in the files themselves (file extension, header blocks etc.). They are enumerated in the AOI metadata standard since they should always be considered to be queryable parameters in any database search.

47. *File.Type (string-CV)*   *all*

Definition: The format of the file. For images this would include:

- **TIFF**
- **JPEG**
- **PNG**
- **GIF**
- **PSD**
- **PDF**

Full list is given in Appendix A

48. *File.Dimension (float, list(2))*   *all*

Definition: Size in pixels (x, y) of the image resource.

49. *File.Size (float)*   *all*

Definition: Size of the image resource, measured in kilobytes.

50. *File.BitDepth (float)*   *all*

Definition: Color bit-depth of the file, measured in total bits per pixel.

Comment: This is typically "8" for GIF or greyscale images, and "24" for other full color formats, though "16" and "48" are possible for greyscale/color images that have 16 bits per channel.

Metadata Extension: FITS Liberator

The XMP format for embedded metadata tags within image files easily allows for extension to accommodate special purpose needs. The example presented here is employed by the Photoshop FITS Liberator to record all of the image stretch function settings used during import of a dataset.

These metadata tags are not part of the AOI standard but are included as an example of how special purpose extensions can be developed under this framework. In particular, these numbers should not suggest the original FITS data values can be recovered through any inverse transforms, since any further edits in Photoshop would invalidate the transform.

These tags are all of the same ordered list sequence as the image band tags under Observation Metadata.

51. *FL.StretchFunction (string-CV, list-ordered)*

Definition: Stretch function applied to the input data in the processing. One StretchFunction per exposure.

Comment: Some possibilities include: Linear, Logarithmic etc. Consult Appendix A for specific options for this tag.

52. *FL.BackgroundLevel (float, list-ordered)*

Definition: Lower value of input range for the Scale function. One BackgroundLevel per exposure.

Comment: This value will become the minimum in the Scaled image.

53. *FL.PeakLevel (float, list-ordered)*

Definition: Upper value of input range for the Scale function. One PeakLevel per exposure.

Comment: This value will become the maximum in the Scaled image.

54. *FL.ScaledBackgroundLevel (float, list-ordered)*

Definition: The target lower value of the range of the Scaled image. One ScaledBackgroundLevel per exposure.

Comment: This value is the defined minimum in the Scaled image.

55. *FL.ScaledPeakLevel (float, list-ordered)*

Definition: The target upper value of the range of the Scaled image. One ScalePeakLevel per exposure.

Comment: This value is the defined maximum in the Scaled image.

56. *FL.BlackLevel (float, list-ordered)*

Definition: The Stretched Scaled input pixel value, which was set to define the color black in the output image. One BlackLevel per exposure.

57. *FL.WhiteLevel (float, list-ordered)*

Definition: The Stretched Scaled input pixel value, which was set to define the color white in the output image. One WhiteLevel per exposure.

58. FL.CreationNotes (string)

Definition: Free-form notes about the image creation process.

Appendix A: Controlled Vocabularies

14. Subject.Category: Astronomical Object Taxonomy

The purpose of this tag is to characterize the subject matter of an image or illustration. More than one element from this taxonomy may be listed in this field to provide a more complete description.

A valid entry in this field may conclude at any level in this hierarchy depending on the level of specificity desired. The only exception is that bracketed elements in the taxonomy are not meaningful alone; they provide logical divisions for different classes of subcategories.

Note that names of specific objects do not belong in the 14. Subject.Category tag as these are all generic instances. The 15. Subject.Name tag is used to identify particular objects.

Examples

1. An image of the Earth from space:
    ```
    A.1.1.1 Solar System:Planet:[Type]:Terrestrial
    ```

2. An illustration of a circumstellar disk surrounding a young star in the Milky Way:
    ```
    B.3.1.1 Milky Way:Star:[Evolutionary Stage]: Protostar ;
    B.3.7.2.1 Milky Way:Star:Circumstellar
    Material:Disk:Protoplanetary
    ```

3. An image of the galaxy M82:
    ```
    C.5.1.6 Local Universe:Galaxy:[Type]:Irregular ; C.5.3.3 Local
    Universe:Galaxy:[Activity]:Starburst
    ```

4. A photograph of the Hubble Space Telescope:
    ```
    A.8.1.2 Solar System:Technology:Observatory:Telescope ; A.8.2.1
    Solar System:Technology:Spacecraft:Orbiter
    ```

Top Level Hierarchy

The letter in front of the taxonomy defines the astronomical "scale" of the object (i.e. whether it is a planet in the Solar System or the Milky Way). Note that some options like, A:Nebula:Star formation (a star-forming nebula in the Solar System) are not meaningful. The most typical taxonomy categories that will be used with a given top-level element are specified for clarity, though in principle there could be exceptions to this rule.

A.   Solar System: local to our solar system
            Typical taxonomy types: 1–3, 7–8
B.   Milky Way: contained within the Milky Way galaxy
            Typical taxonomy types: 1–4
C.   Local Universe: current "era" of the universe
            Typical taxonomy types: 3–5

D.   Early Universe: era of galaxy formation and before
            Typical taxonomy types: 5–6
E.   Unspecified: for generic instance of subject
            Typical taxonomy types: any

Image Taxonomy Hierarchy

1. Planet
    1.1. [Type]
        1.1.1. Terrestrial
        1.1.2. Gas Giant
    1.2. [Feature]
        1.2.1. Surface
            1.2.1.1.Mountain
            1.2.1.2.Canyon
            1.2.1.3.Volcanic
            1.2.1.4.Impact
            1.2.1.5.Erosion
            1.2.1.6.Liquid
            1.2.1.7.Ice
        1.2.2. Atmosphere
            1.2.2.1.Cloud
            1.2.2.2.Storm
            1.2.2.3.Belt
            1.2.2.4.Aurora
    1.3. [Special Cases]
        1.3.1. Transiting
        1.3.2. Hot Jupiter
        1.3.3. Pulsar planet
    1.4. Satellite
        1.4.1. [Feature]
            1.4.1.1.Surface
                1.4.1.1.1. Mountain
                1.4.1.1.2. Canyon
                1.4.1.1.3. Volcanic
                1.4.1.1.4. Impact
                1.4.1.1.5. Erosion
                1.4.1.1.6. Liquid
                1.4.1.1.7. Ice
            1.4.1.2.Atmosphere
    1.5. Ring
2. Interplanetary Body
    2.1. Comet
        2.1.1. Nucleus
        2.1.2. Coma
        2.1.3. Tail
            2.1.3.1.Dust
            2.1.3.2.Gas
    2.2. Asteroid
    2.3. Meteoroid
3. Star
    3.1. [Evolutionary Stage]
        3.1.1. Protostar
        3.1.2. Young Stellar Object
        3.1.3. Main Sequence
        3.1.4. Red Giant
        3.1.5. Red Supergiant
        3.1.6. Blue Supergiant
        3.1.7. White Dwarf
        3.1.8. Supernova
        3.1.9. Neutron Star
            3.1.9.1.Pulsar
            3.1.9.2.Magnetar
        3.1.10. Black Hole
    3.2. [Type]
        3.2.1. Variable
            3.2.1.1.Pulsating
            3.2.1.2.Irregular
            3.2.1.3.Eclipsing
            3.2.1.4.Flare Star
            3.2.1.5.Nova
        3.2.2. Carbon
        3.2.3. Brown Dwarf
        3.2.4. Wolf-Rayet
        3.2.5. Blue Straggler
        3.2.6. Exotic
    3.3. [Spectral Type]
        3.3.1. O
        3.3.2. B
        3.3.3. A
        3.3.4. F
        3.3.5. G
        3.3.6. K
        3.3.7. M
        3.3.8. L
        3.3.9. T
    3.4. [Population]
        3.4.1. I
        3.4.2. II

7.1.4.3.Satellite
7.1.5.   Zodiacal Light
    7.1.5.1.Gegenschein
7.1.6.   Night glow
7.2. Eclipse
7.2.1.   Solar
    7.2.1.1.Total
    7.2.1.2.Partial
    7.2.1.3.Annular
7.2.2.   Lunar
    7.2.2.1.Total
    7.2.2.2.Partial
    7.2.2.3.Penumbral
7.2.3.   Occultation
7.2.4.   Transit
7.3. Light Phenomenon
7.3.1.   Sunrise-Sunset
    7.3.1.1.Green flash
    7.3.1.2.Refractive Distortion
    7.3.1.3.Sun Pillar
7.3.2.   Cloud
    7.3.2.1.Iridescent
    7.3.2.2.Noctilucent
    7.3.2.3.Nacreous
    7.3.2.4.Corona

7.3.2.5.Glory
7.3.3.   Rainbow
    7.3.3.1.Moonbow
    7.3.3.2.Fogbow
7.3.4.   Halo
    7.3.4.1.Circle
    7.3.4.2.Parhelia
    7.3.4.3.Arc
7.3.5.   Ray-Shadow
    7.3.5.1.Crepuscular ray
    7.3.5.2.Anti-crepuscular ray
    7.3.5.3.Earth shadow
7.3.6.   Lightning
7.3.7.   Aurora
8.   Technology
8.1. Observatory
    8.1.1.   Facility
    8.1.2.   Telescope
    8.1.3.   Instrument
8.2. Spacecraft
    8.2.1.   Orbiter
    8.2.2.   Probe
    8.2.3.   Lander
    8.2.4.   Manned

21. Type: VO Resource Type

The scope of this document only covers the following two types from the document "Resource Metadata for the Virtual Observatory Version 1.1". Thus the only acceptable values for this tag are:

- **Artwork** – Artists' renderings of astronomical phenomena or objects
- **Photographic** – Publication-quality photographs of astronomical objects.

24. Spectral.ColorAssignment

The values of the color mapping come from a limited list of common colors. Additional information about color mapping may be entered in the free text tag Spectral.Notes.

- **Purple**
- **Blue**
- **Cyan**
- **Green**
- **Yellow**
- **Orange**
- **Red**
- **Magenta**
- **Grayscale** – for single-channel image
- **Pseudocolor** – for single channel image with color mapped to intensity

25. Spectral.Band: General Wavelength Regime

The acceptable values for this tag are taken to match the definitions from the document "Resource Metadata for the Virtual Observatory Version 1.1":

Coverage.Spectral	Represents
Radio	$\lambda \geq 10$ mm
	$\nu \leq 30$ GHz
Millimeter	0.1 mm $\leq \lambda \leq$ 10 mm
	3000 GHz $\geq \nu \geq$ 30 GHz
Infrared	1 $\mu \leq \lambda \leq$ 100 μ
Optical	0.3 $\mu \leq \lambda \leq$ 1 μ
	300 nm $\leq \lambda \leq$ 1000 nm
	3000 Å $\leq \lambda \leq$ 10000 Å
Ultraviolet	0.01 $\mu \leq \lambda \leq$ 0.3 μ
	100 Å $\leq \lambda \leq$ 3000 Å
	1.2 eV $\leq E \leq$ 120 eV
X-ray	0.1 Å $\leq \lambda \leq$ 100 Å
	0.12 keV $\leq E \leq$ 120 keV
Gamma-ray	$E \geq 120$ keV

32. Spatial.CoordinateFrame

The values for the coordinate system follow CDS Aladin conventions and may adopt the following values.

- **ICRS** – epoch-independent system
- **FK5** – default J2000 epoch
- **FK4** – default B1950 epoch
- **ECL** – ecliptic coordiantes
- **GAL** – galactic coordinates
- **SGAL** – supergalactic coordinates

39. Spatial.CoordSystemProjection

The value for the coordinate system projection may be any accepted WCS projection system. The most common are enumerated below.

- **TAN** – tangent
- **SIN** – sinusoidal
- **ARC** – arc sky
- **AIT** – AITOFF full-sky
- **CAR** – Plate –Careé (rectilinear coordinates)

41. Spatial.Quality: Coordinate Reliability

These terms provide a qualitative assessment of the reliability and completeness of the WCS solution for the image.

- **Full** – Verified full WCS information (though may exclude CD matrix)
- **Position** – Spatial.ReferenceValue describes a coordinate contained somewhere within the image; other WCS info is approximate or unreliable
- **Unknown** – missing or unverified/unreliable

43. ImageProductQuality

Limited terms to describe the subjective quality of the image.

- **Good** – Clean, publication-ready image
- **Moderate** – Some flaws in the image, but of good quality
- **Poor** – Degraded quality; significant artefacts, but still acceptable for reference

47. File.Type: Format of Image

This field contains the file format of the image. This metadata is not in a user-editable tag but is derived from the image suffix/header. Valid formats include the following.

- **TIFF**
- **JPEG**
- **PNG**

- **GIF**
- **PSD**
- **PDF**

51. FL.StretchFunction: FITS Liberator stretch function

The different possible options for the FITS Liberator stretch function:

- Linear

- ArcSinh(x): Inverse hyperbolic sine
- Log(x): Logarithm

- $x^{1/2}$: Square root
- $x^{1/3}$: Cube root
- $x^{1/4}$: 4th root
- $x^{1/5}$: 5th root

- ArcSinh(ArcSinh(x)): Inverse hyperbolic sine of the inverse hyperbolic sine
- ArcSinh($x^{1/2}$): Inverse hyperbolic sine of the square root
- Log(Log(x)): Logarithm of the logarithm
- Log($x^{1/2}$): Logarithm of the square root

-

Appendix B: Abbreviations

AOI   Astronomical Outreach Imagery

ASCII   American Standard Code for Information Interchange

CV   Controlled Vocabulary

ECL   Ecliptic coordinates

EPO   Education and Public Outreach

EXIF   Exchangeable image file format (http://en.wikipedia.org/wiki/Exif)

FITS   Flexible Image Transport System (http://en.wikipedia.org/wiki/FITS)

FK4   Default B1950 coordinate epoch

FK5   Default J2000 coordinate epoch

GAL   Galactic coordinates

GIF   Graphics Interchange Format (http://en.wikipedia.org/wiki/Gif)

ICRS   Epoch-independent coordinate system

IEEE   Institute of Electrical and electronics Engineers

IETF   Internet Engineering Task Force

IPTC   International Press Telecommunications Council
(http://en.wikipedia.org/wiki/IPTC)

IVOA   International Virtual Observatory Alliance

JPEG   Joint Photographic Experts Group (http://en.wikipedia.org/wiki/Jpeg)

PDF   Portable Document Format (http://en.wikipedia.org/wiki/Pdf)

PNG   Portable Network Graphics (http://en.wikipedia.org/wiki/Png)

PSD   Photoshop Document

RGB   RED, GREEN, BLUE

SGAL Supergalactic coordinates

STScI Space Telescope Science Institute (http://www.stsci.edu)

TIFF Tagged Image File Format (http://en.wikipedia.org/wiki/Tiff)

URI Uniform Resource Identifier
(http://en.wikipedia.org/wiki/Uniform_Resource_Identifier)

URL Uniform Resource Locator (http://en.wikipedia.org/wiki/Url)

UTF Unicode Transformation Format

VO Virtual Observatory

WCS World Coordinate System

XMP Extensible Metadata Platform