



International

Virtual

Observatory

Alliance

Astronomy Visualization Metadata (AVM) Standard for the Virtual Astronomy Multimedia Project (VAMP) and other Virtual Observatories.

Version 1.10 - DRAFT
IVOA DRAFT Note 2008 May 14

Working Group:

Not applicable

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Abstract

This document describes a standard for Astronomy Visualization Metadata (AVM) 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 and is the keystone to the VAMP project.

The 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 described here easily integrates 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.

Status of this document

This is an IVOA Proposed Recommendation made available for public review. It is appropriate to reference this document only as a recommended standard that is under review and which may be changed before it is accepted as a full recommendation.

Nov 5 2007: Currently under edit/revision by AJ Gauthier/R Hurt/ LL Christensen.

Jan 5 2008: Revised prior to Jan. 2008 AAS feedback session.

May 14 2008: Final 1.1 revisions completed based on feedback from and subsequent to Jan. 2008 AAS meeting.

Acknowledgements

This document is a product of discussions started in IAU Commission 55 *Communicating Astronomy with the Public* and the subsequent Virtual Repository Working Group, now named the Virtual Astronomy Multimedia Project (VAMP). The editors gratefully acknowledge the many significant comments, discussions, and contributions from the many participants in this group. We have likewise received tremendous feedback and support from the astronomical community. Early implementers of these standards include Microsoft's WorldWide Telescope and Google Sky.

Revision History

AVM Version 1.0: September 2006

AVM Version 1.1: DRAFT October 2007 – May 2008

Modifications from v1.0 to v1.1¹:

- Redesigned informational tables to show proper example metadata, tags, IPTC, and UCD1+ equivalencies/translations
- AVM implementation in XMP expanded and clarified
- Appendices revised and renumbered
 - Addition of a new Appendix C: WCS Representation in the AVM.
 - Deleted AVM to VOTable appendix; better as an online resource than a section in the core schema document.
 - Deleted FITS Liberator Example AVM Extension appendix: not relevant to the core schema document.
- Updated Tags:
 - New Tags
 - **Title** tag (CONTENT²) now holds the data formerly in **Headline**.
 - **Distance** (CONTENT) added.
 - **Distance.Notes** (CONTENT) added.
 - **Spatial.FITSheader** (COORDINATES) added.
 - **MetadataDate** (PUBLISHER) added.
 - **ResourceURL** (PUBLISHER) added.
 - **RelatedResources** (PUBLISHER) added.
 - Modified Tags
 - **Headline** (CONTENT) was slightly redefined.
 - The definition of **Headline** now follows the IPTC standard of a “short description” rather than a “title” for the image as in Version 1.0.
 - “Coverage” removed from the name of **Spatial** tag.
 - **ResourceID** (PUBLISHER) now reflects a content provider’s naming schema for their image files.
 - **Spatial.CDMatrix** (COORDINATES) deprecated.
 - A new **Type** (CONTENT) of image was added: *Collage*.
 - A new **Type** (CONTENT) value *Chart* added
 - **CreatorURL** (CONTENT) now references the IPTC tag *Iptc4xmpCore:CiUrlWork*.
 - **MetadataVersion** now resides in the PUBLISHER tagset.
 - **Subject.Category** (CONTENT) includes several additions
 - 3.2.1.6. X-Ray Binary (Star)
 - 5.4.9. Center/Core (Galaxy)
 - 8.1.4. Detector (Technology)
 - 8.2.5. Launch Vehicle (Technology)
 - 9.x. People (top level category)
 - “X” top level hierarchy for local use

¹ Tags in the main text are denoted by **bold** text, tagsets by SMALL CAPITALS.

² Denotes the tagset

Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

TABLE OF CONTENTS

ABSTRACT	1
STATUS OF THIS DOCUMENT	2
ACKNOWLEDGEMENTS	2
REVISION HISTORY	3
1 OVERVIEW	6
1.1 INTENDED SCOPE OF AVM METADATA SCHEMA.....	6
1.2 METADATA PORTABILITY: XMP.....	7
1.3 REFERENCED STANDARDS	7
1.4 WORLD COORDINATE SYSTEM NOTES.....	8
1.5 IMPLEMENTATION.....	9
2 AVM METADATA TAG OVERVIEW	10
2.1 TAG FORMATS	10
2.2 MULTI-VALUED LISTS.....	10
2.3 TAG SUMMARY TABLE	11
2.4 APPLICABILITY OF METADATA TAG CATEGORIES.....	13
2.5 XMP NAMESPACES UTILIZED BY AVM	13
2.6 RECOMMENDED TAGGING PRACTICES.....	13
2.6.1 <i>Required Tags</i>	13
2.6.2 <i>Semantic Search Tags</i>	14
2.6.3 <i>Observation Tags</i>	14
2.6.4 <i>Coordinate Tags</i>	14
2.6.5 <i>What Should Not Be Tagged</i>	15
3 METADATA TAG DEFINITIONS	16
3.1 CREATOR METADATA	16
3.2 CONTENT METADATA	19
3.3 OBSERVATION METADATA.....	22
3.4 COORDINATE METADATA	25
3.5 PUBLISHER METADATA	29
3.6 FILE METADATA	31
4 APPENDIX A: CONTROLLED VOCABULARIES	33
4.1 SUBJECT.CATEGORY: ASTRONOMICAL OBJECT TAXONOMY	33
4.1.1 <i>Examples</i>	33
4.1.2 <i>Top Level Hierarchy</i>	34
4.1.3 <i>Image Taxonomy Hierarchy</i>	35
4.2 TYPE	38
4.3 IMAGEPRODUCTQUALITY	39
4.4 SPECTRAL.COLORASSIGNMENT.....	39
4.5 SPECTRAL.BAND: GENERAL WAVELENGTH REGIME	39
4.6 SPATIAL.COORDINATEFRAME	40
4.7 SPATIAL.COORDSYSTEMPROJECTION	40
4.8 SPATIAL.QUALITY: COORDINATE RELIABILITY.....	40
4.9 FILE.TYPE: FORMAT OF IMAGE	40
5 APPENDIX B: ABBREVIATIONS	41
6 APPENDIX C: WCS REPRESENTATION IN AVM	42
6.1 WCS BASICS AND TERMINOLOGY	42
6.1.1 <i>Projection</i>	43

Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

6.1.2	<i>Coordinate System</i>	43
6.1.3	<i>Reference Position</i>	43
6.1.4	<i>Scale and Orientation</i>	44
6.1.5	<i>Additional Distortions</i>	44
6.2	WCS REPRESENTATION IN AVM	44
6.2.1	<i>AVM WCS Conventions</i>	45
6.2.2	<i>Image Parity</i>	46
6.2.3	<i>CDMatrix Representations</i>	46
6.2.4	<i>AVM WCS and Rescaled Images</i>	47
6.2.5	<i>FITS Headers and Distortion Correction Terms</i>	47
6.3	AVM-FITS CONVERSIONS	48
6.3.1	<i>Data Descriptor vs. Image Format</i>	48
6.3.2	<i>Mapping AVM Tags and FITS Keywords</i>	49
6.3.3	<i>CDELTA, CROT, and CD Matrix Values</i>	49
6.3.4	<i>FITS Image Parity and AVM Tags</i>	50
6.3.5	<i>Constructing a FITS Header from AVM Tags</i>	51
6.4	OTHER INFORMATION	51
6.4.1	<i>Best Practices for AVM WCS Implementations</i>	51
6.4.2	<i>WCS Notes for Developers</i>	52
6.4.3	<i>WCS FAQ</i>	52
6.4.4	<i>WCS References</i>	53
7	APPENDIX D: XMP ACCESS AND EXAMPLES	54
7.1	XMP PROGRAMMING ACCESS	54
7.2	XMP LIST FORMATS	54
7.3	XMP REFERENCE HEADER FILE	54
7.4	XMP REFERENCE COMPACT JPEG HEADER FILE	57
7.5	LOCAL-USE CUSTOM XMP TAGS	58
8	APPENDIX E: AVM FULL PROPERTIES SUMMARY TABLE	59

1 Overview

This document defines metadata tags that describe the Astronomy Visualization Metadata (AVM). This metadata schema has been developed within the framework of the IAU *Virtual Astronomy Multimedia Project* (VAMP)³.

1.1 Intended Scope of AVM Metadata Schema

The astronomical education and public outreach (EPO) community plays a vital 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.



This image of M82 combining x-ray, visible, and infrared light from three observatories is typical example of the kind of visual resources with rich contextual information ideal for AVM tagging.

Just as Virtual Observatory (VO) standards open up all data archives to a common query engine, the EPO community will benefit greatly from a similar mechanism to facilitate 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 and screen ready astronomical imagery that 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 is covered in some detail in later sections.

The intended users of astronomical imagery cover a broad variety of fields: educators, students, journalists, enthusiasts, and scientists. The core set of required tags defines the key elements needed in a practical database for the identification of desired resources. For example, one might choose to search for images of the Crab Nebula that include both X-ray and visible light elements, or for any images within two degrees of a specified location on the sky that include at least some data from the Spitzer Space Telescope.

³ For more info see the VAMP homepage at <http://virtualastronomy.org>

Future plans include adding “multimedia modules” and “planetarium modules” into the AVM standard.

1.2 Metadata Portability: XMP

The metadata used to characterize an image are only useful if they remain easily associated with the image for all users. Once an image is separated from its source web page, any contextual information is generally lost, including, most importantly, the original source of the image.

The AVM standard therefore encompasses not only the span of metadata tags, but an implementation for embedding these tags directly within the image file itself. This keeps the metadata available even for “loose” images.

The Adobe© Extensible Metadata Platform (XMP)⁴ specification describes a widely used method for embedding descriptive metadata within images. XMP tags are stored within the image header of all common image formats (JPEG, TIFF, PNG, GIF, PSD) and can be read by popular image processing and cataloging packages. The XMP standard is also widely used by photographers and the publication industry. Users of 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. In practice an XMP header is a block of XML text included in the header block of the image file and is only supported in image types with header/comment blocks.

The advantages of embedded image identity metadata are numerous. Including metadata effectively makes the images self-documenting, which is particularly useful when the source URL for an image is lost. This information can now be accessed by multimedia management packages, or indexed by databases designed to read the embedded information. For instance, an online or desktop planetarium program could load an image from the web and extract the appropriate metadata to place it in the proper position in the sky.

There are other potential long-term benefits of embedding the AVM metadata using XMP. In principle, any such tagged image resource should be searchable and indexed regardless of the actual host or online provider of the image. This standard is intended to open up the opportunities for publication to a much greater 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. Alternatively the image files could be uploaded to a curated site that itself might interface with other online archives such as those offered through “virtual observatory” (VO) projects.

1.3 Referenced Standards

The schema described here has been developed within several existing standards. These include the International Virtual Observatory Alliance (IVOA),

⁴ Adobe XMP, Adding Intelligence to Media: <http://www.adobe.com/products/xmp/>

the International Press Telecommunications Council (IPTC)⁵, and the Adobe© Extensible Metadata Platform (XMP).

The specifications for the World Coordinate System (WCS) descriptors were drawn directly from the IVOA *Simple Image Access Specification Version 1.0*⁶. This allows for possible interoperability with other systems based on this specification.

Translations between the AVM and IVOA vocabularies (like the Resource Metadata⁷ or Unified Content Descriptors (UCD)⁸) are possible. The equivalent UCD tags are listed in Table 3.2. Resource Metadata (RM) are used by VOs to describe an entire collection while the UCDs are used to describe components of an individual dataset within a controlled vocabulary framework.

The methods for embedding metadata directly within the image files are described within the Adobe© XMP specification⁹. This provides an XML system for encoding the data, methods for directly editing the tags within Adobe© Photoshop¹⁰, as well as a developer's Software Development Kit¹¹ for developing custom software applications to read the embedded tags.

The IPTC has utilized an extensive XMP metadata schema¹² for embedding descriptive information within photographs. IPTC standards are widely used in the publication industry and amongst professional photographers for tracking image sources, headlines, and related data. As there is substantial overlap between IPTC tags and those defined in the AVM standard, any AVM tag that directly corresponds to an IPTC tag is mapped into the existing IPTC slot. This provides the benefit that many established publication workflows will automatically access the most general AVM metadata (providing identification, background, credits, etc.).

1.4 World Coordinate System Notes

The AVM metadata standard allows for the inclusion of full 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.

Please see Appendix C for detailed information and discussions on the WCS representation in the AVM.

⁵ IPTC Metadata for XMP: <http://www.iptc.org/IPTC4XMP/>

⁶ Simple Image Access Specification: <http://www.ivoa.net/Documents/latest/SIA.html>

⁷ Resource Metadata for the Virtual Observatory: <http://www.ivoa.net/Documents/latest/RM.html>

⁸ An IVOA Standard for Unified Content Descriptors:
<http://www.ivoa.net/Documents/latest/UCDlist.html> and Maintenance of the list of UCD words:
<http://www.ivoa.net/Documents/latest/UCDlistMaintenance.html>

⁹ Adobe XMP: <http://www.adobe.com/products/xmp/overview.html>

¹⁰ Adobe Photoshop: <http://www.adobe.com/products/photoshop/photoshop/>

¹¹ Adobe XMP Developer Center: <http://www.adobe.com/devnet/xmp/>

¹² IPTC Metadata for XMP: <http://www.iptc.org/IPTC4XMP/>

1.5 Implementation

Current tools for entry of AVM metadata tags are available as part of the ESA/ESO/NASA Photoshop *FITS Liberator*¹³ Version 2.2, released in March 2008. *FITS Liberator* is being developed as one convenient tool for the creation of publication-ready imagery by importing astronomical FITS image files into Photoshop.

Part of the *FITS Liberator* installation includes XMP Custom File Info panels. These allow the AVM metadata to be entered directly into forms under the “File Info...” dialog box. They also allow the AVM tags to be read and edited using the Adobe Bridge application as well.

The *FITS Liberator* plug-in can also populate the AVM fields during the conversion between FITS data and the image. It will populate some of the fields automatically using information pulled from the FITS header. It also offers a subject taxonomy editor to simplify entry of subject codes.

Additionally, stand-alone web tools are under development at ESA/Hubble to pursue a method of tagging that is Adobe-independent. These alpha-version tools include: an AVM Tagging Tool, CSV to XMP script and a Subject.Category Generator. These tools can be found at <http://virtualastronomy.org>.

Please find our *AVM Users Guide for Dummies* and current AVM XMP panels for Adobe Photoshop (and Bridge) on our website:

http://virtualastronomy.org/avm_metadata.php

In principle the XMP tags can be read directly from the image headers; they exist as XML text preceding the image data. Thus any software developer can access the tags by parsing the XML text. Adobe also offers a Software Developer’s Kit (SDK) for several languages to aid in XMP software development.

As stand-alone tools become available for editing, extracting, and using AVM metadata they will be made available to the community as well. Other such tools should include an automated method to copy XMP metadata into a database/XML files, and strategies to weed out the non-AVM XMP tags. Please see Appendix D for a sample XMP file.

¹³ FITS Liberator: http://www.spacetelescope.org/projects/fits_liberator

2 AVM Metadata Tag Overview

2.1 Tag Formats

The metadata tags are physically stored as strings within an XMP header, but many tags are expected to follow a specific format. Each of the metadata tags has one of several possible formats summarized below.

- **String** – a free-format text field.
- **String-CV** – a string that should only contain values from a “controlled vocabulary” (CV) list.
- **Float** – a numeric value that may be expressed as integer, decimal, or floating-point scientific forms.
- **Date** – a date in ISO 8601 format YYYY-MM-DDTHH:MM (the time term is optional)
- **URL** – universal resource locator; a standard web address.

“Controlled vocabulary” items use predefined values to facilitate database searching by using standardized terminology. All controlled vocabulary lists for tags may be found in Appendix A.

Some data entry methods (like Photoshop “File Info...” panels) may require the date be entered using a localized format (like MM/DD/YYYY), but this will be represented internally as YYYY-MM-DD in the ISO 8601 format.

2.2 Multi-valued Lists

Many tags are specified to be a “list,” which can contain multiple elements. The semicolon “;” separates different list elements for common methods of data entry, although the internal XMP representation uses delimiting XML tags. There are several different styles of list:

- List – can have any number of elements; order is irrelevant.
- List(2) – has exactly two ordered elements.
- List(s) – has a number of ordered elements equal to the number of source images, *s*, in a color composite.

The “list(s)” property applies specifically to a set of OBSERVATION tags describing the nature of specific color channels in composite images 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 list-ordered would contain the information for each FITS file in the same sequential order.

Null values in List(2) and List(s) should be represented with a dash “-” character. This may be useful as a placeholder to reserve a slot explicitly without a value to maintain the correct ordering of the remaining elements.

2.3 Tag Summary Table

The following table summarizes the tag names and formats in addition to providing example values. Detailed descriptions appear in Section 3.

AVM Tag Name	Format	Example
3.1 Creator Metadata		
Creator	string	Spitzer Science Center
CreatorURL	URL	http://www.spitzer.caltech.edu
Contact.Name	string, list	R. Hurt
Contact.Email	string, list	example@ipac.caltech.edu
Contact.Telephone	string, list	555-555-5555
Contact.Address	string	1200 E. California Blvd.
Contact.City	string	Pasadena
Contact.StateProvince	string	California
Contact.PostalCode	string	91125
Contact.Country	string	USA
Rights	string	Public Domain
3.2 Content Metadata		
Title	string	M 82
Headline	string	The galaxy M82 is seen across the spectrum from X-rays to infrared light. This combined view is from NASA's Chandra, Hubble, and Spitzer telescopes.
Description	string	NASA's Spitzer, Hubble, and Chandra space observatories teamed up to create this multi-wavelength, false-colored view of the M82 galaxy. High energy particles appear as blue, stars as green, dust as red.
Subject.Category	string-CV, list	C.5.1.6;C.5.3.3
Subject.Name	string, list	M 82; Messier 82; NGC 3034; Cigar Galaxy
Distance	float, list(2)	11700000; 0.000677
Distance.Notes	string	Light years from PI; redshift from NED
ReferenceURL	URL	http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=sig06-010
Credit	string	NASA/JPL-Caltech/STScI/CXC/UofA/ESA/AURA/JHU
Date	date	2007-04-24
ID	string	sig06-010
Type	string-CV	Observation
Image.ProductQuality	string-CV	Good
3.3 Observation Metadata		
Facility	string, list(s)	Chandra; Hubble; Hubble; Spitzer
Instrument	string, list(s)	ACIS; ACS; ACS; IRAC
Spectral.ColorAssignment	string-CV, list(s)	Blue; Green; Orange; Red
Spectral.Band	string-CV, list(s)	X-ray; Optical; Optical; Infrared
Spectral.Bandpass	string, list(s)	;-B;R;mid-infrared

Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

Spectral.CentralWavelength	float, list(s)	0.5;440;700;8000
Spectral.Notes	string	X-ray bandpass wavelengths are approximate.
Temporal.StartTime	date, list(s)	-; 2005-02-05; 2005-02-05; 2004-07-03T12:00
Temporal.IntegrationTime	float, list(s)	-; -; -; 240
DatasetID	string, list(s)	a1;a2;a3;a4

3.4 Coordinate Metadata

Spatial.CoordinateFrame	string-CV	ICRS
Spatial.Equinox	string	2000
Spatial.ReferenceValue	float, list(2)	149.11051168; 69.7053749827
Spatial.ReferenceDimension	float, list(2)	4299; 3490
Spatial.ReferencePixel	float, list(2)	922.146820068; 1153.85690308
Spatial.Scale	float, list(2)	-4.1635027032331E-05; 4.1635027032331E-05
Spatial.Rotation	float	49.93606563
Spatial.CoordsystemProjection	string-CV	TAN
Spatial.Quality	string-CV	Full
Spatial.Notes	string	FOV: 10.74 x 8.72 arcminutes; Ref coordinate: 9h56m26.52s 69d42m19.35s; derived from astrometry.net file sig06-010.fits
Spatial.FITSheader	string	CRVAL1 = 6.3856 CRVAL2 = 64.1784 RADESYS = 'ICRS ' EQUINOX = 2000. CTYPE1 = 'RA---TAN' CTYPE2 = 'DEC--TAN' CRPIX1 = 214. CRPIX2 = 138.
Spatial.CDMatrix (deprecated)	float, list(4)	

3.5 Publisher Metadata

Publisher	string	Spitzer Space Telescope
PublisherID	string	vamp://spitzer
ResourceID	string	sig05-010_jpg_sm
ResourceURL	URL	http://ipac.jpl.nasa.gov/media_images/sig06-010.tif
RelatedResources	list	vamp://spitzer/sig05-010; vamp://spitzer/sig05-010
MetadataDate	date	2008-05-09
MetadataVersion	string	1.1

3.6 File Metadata

File.Type	string-CV	TIFF
File.Dimension	float, list(2)	4299; 3490
File.Size	float, list(2)	18237
File.BitDepth	float	24

2.4 Applicability of Metadata Tag Categories

Some of the metadata categories apply broadly to any astronomy-themed image (including artwork, photographs, etc.) while others are specifically defined for astronomical telescopic observations. This distinction is made in the **Type** tag.

- CREATOR, CONTENT, PUBLISHER, FILE: apply to all image types.
- OBSERVATION: applies to **Type** *Observation* and *Planetary*.
- COORDINATE: applies only to **Type** *Observation* (when available).

For more information, consult section 4.2 in Appendix A.

2.5 XMP Namespaces Utilized by AVM

The XMP standard utilizes a number of different “namespaces” that reference the defining standards for different elements of the metadata. As the metadata standards have expanded over time, newer schemas have always utilized earlier relevant schema for backwards compatibility while adding new terms for increased functionality. AVM has been designed with this philosophy so its XMP implementation utilizes these prior schemas, defined in their namespaces, wherever possible.

The namespaces consist of a case-sensitive shorthand tag (which appears in the XML markup for the metadata) and a URL reference to the defining standard. Those utilized by AVM are listed below.

avm	http://www.communicatingastronomy.org/avm/1.0/
iptc4xmpCore	http://iptc.org/std/Iptc4xmpCore/1.0/xmlns/
dc	http://purl.org/dc/elements/1.1/
photoshop	http://ns.adobe.com/photoshop/1.0/
xapRights	http://ns.adobe.com/xap/1.0/rights/

2.6 Recommended Tagging Practices

To form a meaningful database for user searches, implementing certain sets of AVM metadata tags is strongly encouraged. If an observational image of the Sombrero Galaxy is not tagged with WCS coordinates then it will not, for instance, be found and used by desktop planetarium software. Obviously, the more completely an image is tagged, the more utility it has. Some key considerations are outlined below.

2.6.1 Required Tags

A minimum set of tags is required to define an image and uniquely identify the resource and origin. These include:

- **MetadataVersion** (PUBLISHER)
- **Creator** (CREATOR)
- **Rights** (CREATOR)
- **Credit** (CONTENT)
- **ID** (CONTENT)
- **ResourceID** (PUBLISHER)

The following tags (the FILE tagset) are implicit in the image resource as they are the standard file properties. These tags represent values that are not user-editable and are derived from the image properties directly:

- **File.Type**
- **File.Dimension**
- **File.Size**
- **File.BitDepth**

2.6.2 Semantic Search Tags

The following tags are highly useful to aid identification of resources in semantic searches and are strongly encouraged.

- **Title** (CONTENT)
- **Headline** (CONTENT)
- **Description** (CONTENT)
- **Subject.Category** (CONTENT)
- **Subject.Name** (CONTENT)
- **Facility** (OBSERVATION)
- **Instrument** (OBSERVATION)

2.6.3 Observation Tags

Observations based on astronomical imagery can often be hard to interpret, particularly if they contain data from multiple instruments or observatories. Completing a core set of OBSERVATION tags will unambiguously identify the data sources and interpretations of colors in a composite image:

- **Facility**
- **Spectral.ColorAssignment**
- **Spectral.Band**
- **Spectral.CentralWavelength**

2.6.4 Coordinate Tags

Images based on astronomical observations can, in principle, be tagged with World Coordinate System (WCS) information giving partial or full access to their location, scale, and orientation in the sky.

The presence of basic coordinate information indicating the sky position of an arbitrary position in the image is useful for a basic positional association. It can, for instance, allow the image to be identified in a cone search query. The following COORDINATE tags will specify this:

- **Spatial.CoordinateFrame**
- **Spatial.Equinox**
- **Spatial.ReferenceValue**
- **Spatial.Quality = "Position"**

Inclusion of a full set of spatial tags will allow the image to be projected in its proper sky position. This requires the additional COORDINATE tags:

- **Spatial.ReferenceDimension**
- **Spatial.ReferencePixel**
- **Spatial.Scale**
- **Spatial.Rotation**
- **Spatial.CoordsystemProjection**
- **Spatial.Quality = "Full"**

2.6.5 What Should Not Be Tagged

The XMP header containing the AVM tags can grow to be large, especially if extensive caption and comment text is included. For large images this is a small fraction of the overall image size, but it can become burdensome for smaller images.

Only images intended for distribution and local use by other users should be tagged. Images that are intended only for online viewing, especially very small thumbnails, should **not** be tagged. If, for instance, thumbnail images intended for display on gallery image index pages are fully tagged, the download times for the page could triple or more!

Typical AVM headers can be as large as 15 kilobytes. This can be large enough to be a burden on download times for a page containing many thumbnails of comparable size. Typically AVM tags should not be included on small thumbnails or other compact images used on web pages intended for quick downloads.

3 Metadata Tag Definitions

In the following definitions for each tag, the following areas are described:

- **Definition** describes the specific piece of information (metadata) that should be defined by that specific tag.
- **Comments** add extra information to aid in understanding.
- **Format** defines how the tag contents will be parsed by AVM (see *2.1 Tag Formats*). Note that XMP will accept any free text for a tag, but tags that do not conform to the specified format cannot be interpreted by AVM readers.
- **XMP Tag** shows the XML markup that surrounds each tag element. Some formats use nested markups. Each tag will be closed with corresponding markups with leading “/” characters (e.g. `<avm:ID>id_tag_text</avm:ID>`). For list element items, the initial two tags mark the entire list block while list element tags (“`<rdf:li>`”) will block out each of the individual elements.
- **IPTC equivalent** identifies the corresponding common text name for IPTC metadata equivalents, where they exist.
- **Related UCD1+** identifies elements of the IVOA UCD1+ metadata standard that correspond to AVM tags. Note these correspondences are seldom exact; proper translation to IVOA tables will require further interpretation.
- **Example** shows an example of appropriate metadata for a given tag. While every tag is given example metadata, some of it is merely provided to demonstrate format and is not necessarily accurate. In common usage, a given resource may have many blank unused tags.

3.1 Creator Metadata

These tags identify the source of the resources (usually an organization, not an individual) and would likely not change much from product to product from the same content provider.

Creator

Definition:	Original creator of the resource at the organizational level.
Comments:	Required for submission to VAMP Archive
Format:	string
XMP Tag:	<code><photoshop:Source></code>
IPTC/UCD1+:	Source / meta.curation
Example:	Spitzer Science Center

CreatorURL

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

Comments: –

Format: URL

XMP Tag: <Iptc4xmpCore:CiUrlWork>

IPTC/UCD1+: Website(s) / –

Example: <http://www.spitzer.caltech.edu>

Contact.Name

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

Comments: –

Format: string, list

XMP Tag: <dc:creator><rdf:Seq><rdf:li>

IPTC/UCD1+: Creator / –

Example: R. Hurt

Contact.Email

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

Comments: –

Format: string, list

XMP Tag: <Iptc4xmpCore:CiEmailWork>

IPTC/UCD1+: E-Mail(s) / meta.email

Example: example@ipac.caltech.edu

Contact.Telephone

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

Comments: –

Format: string, list

XMP Tag: <Iptc4xmpCore:CiTelWork>

IPTC/UCD1+: Phone(s) / –

Example: 555-555-5555

Contact.Address

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

Comments: –

Format: string

XMP Tag: <Iptc4xmpCore:CiAdrExtadr>

IPTC/UCD1+: Address / –

Example: 1200 E. California Blvd.

Contact.City

Definition: City of the primary contact for the resource.
Comments: –
Format: string
XMP Tag: <Iptc4xmpCore:CiAdrCity>
IPTC/UCD1+: City / –
Example: Pasadena

Contact.StateProvince

Definition: State or province of the primary contact for the resource.
Comments: –
Format: string
XMP Tag: <Iptc4xmpCore:CiAdrRegion>
IPTC/UCD1+: State/Province / –
Example: California

Contact.PostalCode

Definition: Zip or postal code of the primary contact for the resource.
Comments: –
Format: string
XMP Tag: <Iptc4xmpCore:CiAdrPcode>
IPTC/UCD1+: Postal code / –
Example: 91125

Contact.Country

Definition: Country of the primary contact for the resource.
Comments: –
Format: string
XMP Tag: <Iptc4xmpCore:CiAdrCtry>
IPTC/UCD1+: Country / –
Example: USA

Rights

Definition:	Copyright and related intellectual property rights description.
Comments:	Required for submission to VAMP Archive. Without copyright and rights management information, the VAMP Archive will not be able to serve out images and metadata properly and legally. Public domain/free use images/metadata are of the greatest utility to the community.
Format:	string
XMP Tag:	<xapRights:UsageTerms><rdf:Alt><rdf:li xml:lang="x-default">
IPTC/UCD1+:	Rights Usage Terms / –
Example:	Public Domain

3.2 Content Metadata

This set of tags contains the contextual information for an image. This information is useful for semantic searches to identify images by content.

Title

Definition:	General descriptive title given to the image resource.
Comments:	This should only contain a single line of text.
Format:	string
XMP Tag:	<dc:title><rdf:Alt><rdf:li xml:lang="x-default">
IPTC/UCD1+:	Title / –
Example:	M 82

Headline

Definition:	Short description of the full caption.
Comments:	This can contain up to two or three brief sentences.
Format:	string
XMP Tag:	<photoshop:Headline>
IPTC/UCD1+:	Headline / meta.title
Example:	The galaxy M82 is seen across the spectrum from X-rays to infrared light. This combined view is from NASA's Chandra, Hubble, and Spitzer telescopes.

Description

Definition:	Full caption and related description text for the image resource.
Comments:	This may contain full paragraphs of information about the resource.
Format:	string
XMP Tag:	<dc:description><rdf:Alt><rdf:li xml:lang="x-default">
IPTC/UCD1+:	Description / meta.note
Example:	NASA's Spitzer, Hubble, and Chandra space observatories teamed up to create this multi-wavelength, false-colored view of the M82 galaxy. High energy particles appear as blue, stars as green, dust as red.

Subject.Category

Definition: The type(s) of object or objects in the resource, or general subject matter of an image, taken from a controlled vocabulary taxonomy (see appendix A)

Comments: If objects can be placed into multiple categories in the taxonomy they should all be listed.

Format: string-CV, list

XMP Tag: <avm:Subject.Category><rdf:Bag><rdf:li>

IPTC/UCD1+: – / –

Example: C.5.1.6;C.5.3.3

Subject.Name

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

Comments: Common catalog numbers (e.g. Messier, NGC, IC, 3C) and common names should be used here. Spaces should be used to separate catalog designations and numbers (e.g. "NGC 1250" not "NGC1250") and leading zeros should be omitted (e.g. "M 5" not "M 05"). When common catalog numbers are not available, any published identification is acceptable (including IDs from standard reference papers). Proper names of non-astronomical subjects should be entered here as well (people, telescopes, facilities, etc.). These tag values will be visible in the "Keyword" field in IPTC-aware applications.

Format: string, list

XMP Tag: <dc:subject><rdf:Bag><rdf:li>

IPTC/UCD1+: Keywords / meta.id

Example: M 82; Messier 82; NGC 3034; Cigar Galaxy

Distance

Definition: The distance to the object, measured in light years (list element 1) and/or redshift (list element 2).

Comments: This tag is an ordered list that may take two independent values. The first is a distance measured in light years, the second is an observed redshift. Either or both of these terms may be entered; if only a redshift is to be entered then a null dash "-" value should be used as a placeholder in the first element. No placeholder is necessary if only the first element is used. **Distance** tags are intended for extrasolar objects giving an approximate estimate to the object. Solar System object distances are highly variable because of orbital mechanics and are best determined from appropriate ephemerides.

Format: float, list(2)

XMP Tag: <avm:Distance><rdf:Seq><rdf:li>

IPTC/UCD1+: – / –

Example: 11700000; 0.000677

Distance.Notes

Definition: Comment about the contents of the **Distance** tag.

Comments: This is useful primarily as a reference to someone evaluating the quality and source of the distance estimate. This tag is free-text, but inclusion of a brief description of the type of measurement and the reference/citation would be appropriate here.

Format: string

XMP Tag: <avm:Distance.Notes>

IPTC/UCD1+: – / –

Example: Light years from PI; redshift from NED

ReferenceURL

Definition: Webpage containing more information about this specific image.

Comments: This link should point to a full web page with text describing the image, not just to the image file itself. See also **ResourceURL**.

Format: URL

XMP Tag: <avm:ReferenceURL>

IPTC/UCD1+: – / meta.ref.url

Example: http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=sig06-010

Credit

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

Comments: Image credit should always be provided with images. See also **Rights**. Required for submission to VAMP Archive.

Format: string

XMP Tag: <photoshop:Credit>

IPTC/UCD1+: Provider / meta.curation

Example: NASA/JPL-Caltech/STScI/CXC/UofA/ESA/AURA/JHU

Date

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

Comments: This is the release date for the media resource. Note that this is distinct from the observation date (see **Temporal.StartTime**).

Format: date

XMP Tag: <photoshop:DateCreated>

IPTC/UCD1+: Date Created / time.release

Example: 2007-04-24

ID

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

Comments: Multiple versions of the same resource rendered at different sizes or file types (but identical in content) should all have the same **ID**. The different instances will be differentiated from one another by their differing **ResourceID** values.

Format: string

XMP Tag: <avm:ID>

IPTC/UCD1+: – / –

Example: sig06-010

Type

Definition: The type of image/media resource. The controlled vocabulary is listed in Appendix A.

Comments: This allows image and other media resources to be categorized into general categories, distinguishing between, for example, data-derived images and artwork.

Format: string-CV

XMP Tag: <avm:Type>

IPTC/UCD1+: – / –

Example: Observation

Image.ProductQuality

Definition: Qualitative image quality assessment. The controlled vocabulary is listed in Appendix A

Comments: –

Format: string-CV

XMP Tag: <avm:Image.ProductQuality>

IPTC/UCD1+: – / –

Example: Good

3.3 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) 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(s)* 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(s)* tags should identify the contents of the red, green, and blue channels respectively.

Facility

Definition: Telescopes or observatories used for the observations.

Comments: For this and subsequent OBSERVATION keywords, the ordered list allows each contributing observation in a color composite to be identified uniquely. The ordering of the observations should be identical for each list(s) formatted tag.

Format: string, list(s)

XMP Tag: <avm:Facility><rdf:Seq><rdf:li>

IPTC/UCD1+: – / instr.tel

Example: Chandra; Hubble; Hubble; Spitzer

Instrument

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

Comments: –

Format: string, list(s)

XMP Tag: <avm:Instrument><rdf:Seq><rdf:li>

IPTC/UCD1+: – / Instr

Example: ACIS; ACS; ACS; IRAC

Spectral.ColorAssignment

Definition: The output color that is assigned to an exposure. One **Spectral.ColorAssignment** entry per exposure. The controlled vocabulary is listed in Appendix A.

Comments: –

Format: string-CV, list(s)

XMP Tag: <avm:Spectral.ColorAssignment><rdf:Seq><rdf:li>

IPTC/UCD1+: – / –

Example: Blue; Green; Orange; Red

Spectral.Band

Definition: Waveband of the component exposure from a pre-defined list defining the general part of the spectrum covered. One **Spectral.Band** entry per exposure. The controlled vocabulary is listed in Appendix A.

Comments: 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.

Format: string-CV, list(s)

XMP Tag: <avm:Spectral.Band><rdf:Seq><rdf:li>

IPTC/UCD1+: – / em.[band], referring to one of the following: em.radio, em.mm, em.IR, em.opt, em.UV, em.X-ray, em.gamma.

Example: X-ray; Optical; Optical; Infrared

Spectral.Bandpass

Definition: Bandpass of the individual exposure. One **Spectral.Bandpass** entry per exposure.

Comments: 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 (H-alpha, SIII, CO(3-2), etc.), or if appropriate, instrument specific channels or filters (only if no other descriptor is adequate).

Format: string, list(s)

XMP Tag: <avm:Spectral.Bandpass><rdf:Seq><rdf:li>

IPTC/UCD1+: - / em.[band].[range] E.g. em.IR.3-4um. See the *UCD1+ controlled vocabulary Version 1.23*

Example: -;B;R;mid-infrared

Spectral.CentralWavelength

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

Comments: -

Format: float, list(s)

XMP Tag: <avm:Spectral.CentralWavelength><rdf:Seq><rdf:li>

IPTC/UCD1+: - / em.wl.central

Example: 0.5;440;700;8000

Spectral.Notes

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

Comments: -

Format: string

XMP Tag: <avm:Spectral.Notes><rdf:Alt><rdf:li xml:lang="x-default">

IPTC/UCD1+: - / -

Example: X-ray bandpass wavelengths are approximate.

Temporal.StartTime

Definition: Start time of the exposure in ISO 8601 format "yyyy-mm-ddThh:mm" (UT; time portion is optional). One **Temporal.StartTime** entry per exposure.

Comments: This field can be populated from the FITS keyword DATE-OBS.

Format: date, list(s)

XMP Tag: <avm:Temporal.StartTime><rdf:Seq><rdf:li>

IPTC/UCD1+: - / time.start

Example: -; 2005-02-05; 2005-02-05; 2004-07-03T12:00

Temporal.IntegrationTime

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

Comments: This should be considered to be an approximate measure of the exposure time, but not necessarily an indication of the time of the end of the observation (if added to **Temporal.StartTime**). This field can be populated from the FITS keyword EXPTIME.

Format: float, list(s)

XMP Tag: <avm:Temporal.IntegrationTime><rdf:Seq><rdf:li>

IPTC/UCD1+: – / obs.exposure

Example: -; -; -; 240

DatasetID

Definition: Identifier for the source FITS dataset for each exposure in the image. If available, this can be a VO-compliant reference to the dataset [ivo://AuthorityID/ResourceKey]. One **DatasetID** entry per exposure.

Comments: –

Format: string, list(s)

XMP Tag: <avm:DatasetID><rdf:Seq><rdf:li>

IPTC/UCD1+: – / meta.dataset

Example: a1;a2;a3;a4

3.4 Coordinate Metadata

These tags encapsulate the World Coordinate System (WCS) data necessary to project images derived from sky observations onto their correct locations in the sky. While these tags may be derived from corresponding FITS header keywords, the mapping is not necessarily direct. Consult Appendix C for a detailed discussion of the WCS implementation in AVM and its connection to FITS.

Note that even if a correct WCS solution has been derived for an image, it will be invalidated by cropping and/or rotation. Any such global manipulations of the image will require re-derived WCS tags.

Spatial.CoordinateFrame

Definition: Coordinate system reference frame. **Spatial.CoordinateFrame** should be chosen from a pre-defined list. The controlled vocabulary is listed in Appendix A.

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

Format: string-CV

XMP Tag: <avm:Spatial.CoordinateFrame>

IPTC/UCD1+: – / pos.frame

Example: ICRS

Spatial.Equinox

Definition: Equinox for **Spatial.CoordinateFrame** in decimal years.

Comments: This field can be populated from the FITS keyword: EQUINOX. It is optional for celestial coordinates that have been adjusted to default epoch for the coordinate frame (J2000 for FK5, B1950 for FK4), but otherwise required.

Format: string

XMP Tag: <avm:Spatial.Equinox>

IPTC/UCD1+: – / time.equinox

Example: 2000

Spatial.ReferenceValue

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

Comments: This field can be populated from the FITS keywords: CRVAL1, 2.

Format: float, list(2)

XMP Tag: <avm:Spatial.ReferenceValue><rdf:Seq><rdf:li>

IPTC/UCD1+: – / pos.wcs.crval

Example: 149.11051168; 69.7053749827

Spatial.ReferenceDimension

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

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

Format: float, list(2)

XMP Tag: <avm:Spatial.ReferenceDimension><rdf:Seq><rdf:li>

IPTC/UCD1+: – / pos.wcs.naxis

Example: 4299; 3490

Spatial.ReferencePixel

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

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

Format: float, list(2)

XMP Tag: <avm:Spatial.ReferencePixel><rdf:Seq><rdf:li>

IPTC/UCD1+: – / pos.wcs.crpix

Example: 922.146820068; 1153.85690308

Spatial.Scale

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

Comments: FITS Keywords: CDELTA1, CDELTA2 (or derived from CD matrix). Is required for Simple Image Access operation (as per SIA Specification v. 1.0).

Format: float, list(2)

XMP Tag: <avm:Spatial.Scale><rdf:Seq><rdf:li>

IPTC/UCD1+: – / pos.wcs.scale

Example: -4.1635027032331E-05; 4.1635027032331E-05

Spatial.Rotation

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

Comments: FITS Keywords: CROT/CROTA1/CROTA2. 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).

Format: float

XMP Tag: <avm:Spatial.Rotation>

IPTC/UCD1+: – / –

Example: 49.93606563

Spatial.CoordsystemProjection

Definition: A combination of the coordinate system and the projection of the image. The controlled vocabulary is listed in Appendix A.

Comments: 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.

Format: string-CV

XMP Tag: <avm:Spatial.CoordsystemProjection>

IPTC/UCD1+: – / pos.wcs.ctype

Example: TAN

Spatial.Quality

Definition: This qualitatively describes the reliability of the spatial coordinate information in this metadata. The controlled vocabulary is listed in Appendix A.

Comments: This value needs to be set by the user; it should default to a null (undefined) value unless the user specifically indicates otherwise (even if the WCS coordinates have been read in from the FITS file, rotation and cropping frequently follow, invalidating the WCS solution. Values include: *Full* (verified full WCS information) & *Position* (partial information including at least a **Spatial.ReferenceValue**)

Format: string-CV

XMP Tag: <avm:Spatial.Quality>

IPTC/UCD1+: – / –

Example: Full

Spatial.Notes

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

Comments: This field can be used to include human-readable summaries of the image geometry as well as any other relevant notes.

Format: string

XMP Tag: <avm:Spatial.Notes><rdf:Alt><rdf:li xml:lang="x-default">

IPTC/UCD1+: – / –

Example: FOV: 10.74 x 8.72 arcminutes; Ref coordinate: 9h56m26.52s 69d42m19.35s; derived from astrometry.net file sig06-010.fits

Spatial.FITSheader

Definition: Free-text representation of the FITS header from which the AVM spatial tags were derived.

Comments: This optional field allows the full WCS information in the source FITS header (which may include CD matrix and distortion correction terms beyond the scope of AVM WCS) to be preserved with the image. Note that possible ambiguities in how FITS images are rendered as images may introduce ambiguities in how this information is to be interpreted. Note that including large FITS headers can significantly increase the size of the tagged image!

Format: string

XMP Tag: <avm:Spatial.FITSheader>

IPTC/UCD1+: – / –

Example: CRVAL1 = 6.3856 CRVAL2 = 64.1784 RADESYS =
'ICRS ' EQUINOX = 2000. CTYPE1 = 'RA---TAN'
CTYPE2 = 'DEC--TAN' CRPIX1 = 214. CRPIX2 =
138.

Spatial.CDMatrix

Definition: Matrix representation of scale/rotation terms.
Comments: This tag was present in AVM 1.0 but has been deprecated in 1.1.
Format: float, list(4)
XMP Tag:
IPTC/UCD1+: – / –
Example:

3.5 Publisher Metadata

This set of metadata will be defined by the VAMP Archive and Ingest Service. Each content provider will have a unique **Publisher** and **PublisherID** that will link to the **ResourceID** and **ResourceURL**. Various methods of validation may be employed and content providers will receive **Publisher** information upon registration with the VAMP Archive.

Publisher

Definition: Publisher of the resource
Comments: This is a text description of the person or institution providing the resource to the VAMP archive.
Format: string
XMP Tag: <avm:Publisher>
IPTC/UCD1+: – / meta.curation
Example: Spitzer Space Telescope

PublisherID

Definition: ID of publisher registered as VAMP providers.
Comments: The **PublisherID** will be assigned by the administrators of the VAMP archive server. The **PublisherID** combined with the **ID** uniquely describes an image resource.
Format: string
XMP Tag: <avm:PublisherID>
IPTC/UCD1+: – / –
Example: vamp://spitzer

ResourceID

Definition: This identifies a specific “instance” of a resource; e.g. one image in one file format at one resolution. This allows the same resource (image) to be offered in different formats and resolutions. Together with the **PublisherID**, each registered resource is uniquely identified in the database

Comments: Multiple instances of the same resource differing only in file format, resolution, etc. must have unique **ResourceID** values, but should all share identical **ID** values.

Format: string

XMP Tag: <avm:ResourceID>

IPTC/UCD1+: – / –

Example: sig05-010_jpg_sm

ResourceURL

Definition: A unique URL pointing to the specific online image/image archive is needed to identify where to obtain the image. Each **ResourceID** is paired with a matching **ResourceURL**.

Comments: The embedded URL in the image file reflects its location at the time it was created or downloaded. Obviously if gallery links are changed in the future, this will no longer be valid.

Format: URL

XMP Tag: <avm:ResourceURL>

IPTC/UCD1+: – / –

Example: http://ipac.jpl.nasa.gov/media_images/sig06-010.tif

RelatedResources

Definition: The format is a list of **PublisherID/ID** values that will reference specific resources registered in VAMP (though not specific “instances”).

Comments: The purpose of this tag is to allow publishers to intentionally create links between different resources known to be related in content. This could, for instance, be used to link multiple images of the same object, or to relate a podcast to an image.

Format: list

XMP Tag: <avm:RelatedResources><rdf:Bag><rdf:li>

IPTC/UCD1+: – / –

Example: vamp://spitzer/sig05-010; vamp://spitzer/sig05-010

MetadataDate

Definition: The date of the metadata content for the image.
Comments: If any info is updated in the source files (updated caption, corrected credit, etc., new versions of the same resource in different formats) changing this date flags the VAMP Archive to reload the resources.
Format: date
XMP Tag: <avm:MetadataDate>
IPTC/UCD1+: – / –
Example: 2008-05-09

MetadataVersion

Definition: This is the version of the applied metadata definition.
Comments: –
Format: string
XMP Tag: <avm:MetadataVersion>
IPTC/UCD1+: – / –
Example: 1.1

3.6 File Metadata

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

File.Type

Definition: The format of the file. For images this would include TIFF, JPEG, PNG, GIF, PSD, PDF
Comments: Full list is given in Appendix A
Format: string-CV
XMP Tag: n/a
IPTC/UCD1+: – / –
Example: TIFF

File.Dimension

Definition: Size in pixels (x, y) of the image resource.
Comments: –
Format: float, list(2)
XMP Tag: n/a
IPTC/UCD1+: – / –
Example: 4299; 3490

File.Size

Definition: Size of the image resource, measured in kilobytes.
Comments: –
Format: float, list(2)
XMP Tag: n/a
IPTC/UCD1+: – / –
Example: 18237

File.BitDepth

Definition: Color bit-depth of the file, measured in total bits per pixel.
Comments: –
Format: float
XMP Tag: n/a
IPTC/UCD1+: – / –
Example: 24

4 Appendix A: Controlled Vocabularies

Many of the metadata elements are strings that are restricted to a specific set of values, or “controlled vocabularies.” The controlled vocabularies for all AVM metadata tags are summarized below.

Note that all controlled vocabulary tags are assumed to have an additional “Undefined” value, corresponding to an absent or null entry in this field.

4.1 Subject.Category: Astronomical Object Taxonomy

Currently, the purpose of this tag is to characterize the subject matter or answer the question: “What object or part of an object is in this image?” 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 **Subject.Category** tag as these are all generic instances. The **Subject.Name** tag is used to identify particular objects.

4.1.1 Examples

1. An image of the Earth from space:
A.1.1.1
(meaning — Solar System:Planet:[Type]:Terrestrial)
2. An illustration of a circumstellar disk surrounding a young star in the Milky Way:
B.3.1.1; B.3.7.2.1
(meaning — Milky Way:Star: Circumstellar Material: Disk: Protoplanetary; Milky Way: Star: [Evolutionary Stage]: Protostar)
3. An image of the galaxy M82:
C.5.1.6; C.5.3.3
(meaning: Local Universe: Galaxy:[Type]:Irregular; Local Universe: Galaxy: [Activity]: Starburst)
4. A photograph of the Hubble Space Telescope:
A.8.1.2; A.8.2.1
(meaning — Solar System: Technology: Observatory: Telescope; Solar System: Technology: Spacecraft: Orbiter)

4.1.2 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 ($z \leq 0.1$)
Typical taxonomy types: 3–5
- D. Early Universe: distant galaxies and cosmological epochs ($z > 0.1$)
Typical taxonomy types: 5–6
- E. Unspecified: for generic instance of subject
Typical taxonomy types: any

The division between hierarchies C and D is suggested to fall at redshifts of 0.1. This effectively puts well-known galaxies and common catalogs (Messier, NGC) into the “Local” C regime. This corresponds roughly to the division between the point at which galaxies can be imaged as discrete objects and when they become under- or unresolved dots (obviously this varies by telescope). As a rule of thumb, if the science is more related to cosmology then D is preferred.

Hierarchy E is intended to identify resources that are non-astronomical in nature, or generic instances of astronomical topics. Virtually all resources of type *Photographic* should fall into this bin (while technically a photograph of a telescope was taken within the confines of the Solar System [A], it is not a representation of an astronomical object). Artwork will often be tagged as E unless it illustrates a specific astronomical object.

An additional hierarchy element is available for customized local needs for subject tagging. If the AVM is being used for local project development it is possible there will be categories that have not been implemented in this taxonomy that are nonetheless useful for a specific observatory. Any locally defined taxonomy entries may be entered with an “X” for its top hierarchy. General AVM-compliant applications should ignore any **Subject.Category** that starts with the “X” but local code may use it for custom needs. Example: an observatory website using AVM as a basis for its content management system may require additional categories to fully describe its holdings. By adding new “X.n.m” categories it can store this information along with other AVM data in the XMP header, but users outside of that institution will know that it is nonstandard and can be ignored.

4.1.3 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. Dwarf planet
 - 2.2. Comet
 - 2.2.1. Nucleus
 - 2.2.2. Coma
 - 2.2.3. Tail
 - 2.2.3.1. Dust
 - 2.2.3.2. Gas
 - 2.3. Asteroid
 - 2.4. 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
 - 3.2.1.6. X-Ray Binary (Star)
 - 3.2.2. Carbon
 - 3.2.3. Brown Dwarf
 - 3.2.4. Wolf-Rayet
 - 3.2.5. Blue Straggler
 - 3.2.6. Exotic
 - 3.2.6.1. X-Ray Binary
 - 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
 - 3.4.3. III
 - 3.5. [Feature]
 - 3.5.1. Photosphere
 - 3.5.1.1. Granulation

- 3.5.1.2. Sunspot
- 3.5.2. Chromosphere
 - 3.5.2.1. Flare
 - 3.5.2.2. Facula
- 3.5.3. Corona
 - 3.5.3.1. Prominence
- 3.6. [Grouping]
 - 3.6.1. Binary
 - 3.6.2. Triple
 - 3.6.3. Multiple
 - 3.6.4. Cluster
 - 3.6.4.1. Open
 - 3.6.4.2. Globular
- 3.7. Circumstellar Material
 - 3.7.1. Planetary System
 - 3.7.2. Disk
 - 3.7.2.1. Protoplanetary
 - 3.7.2.2. Accretion
 - 3.7.2.3. Debris
 - 3.7.3. Outflow
 - 3.7.3.1. Solar Wind
 - 3.7.3.2. Coronal Mass Ejection
- 4. Nebula
 - 4.1. [Type]
 - 4.1.1. Interstellar Medium
 - 4.1.2. Star Formation
 - 4.1.3. Planetary
 - 4.1.4. Supernova Remnant
 - 4.1.5. Jet
 - 4.2. [Appearance]
 - 4.2.1. Emission
 - 4.2.1.1. H II Region
 - 4.2.2. Reflection
 - 4.2.2.1. Light Echo
 - 4.2.3. Dark
 - 4.2.3.1. Molecular Cloud
 - 4.2.3.2. Bok Globule
 - 4.2.3.3. Proplyd
- 5. Galaxy
 - 5.1. [Type]
 - 5.1.1. Spiral
 - 5.1.2. Barred
 - 5.1.3. Lenticular
 - 5.1.4. Elliptical
 - 5.1.5. Ring
 - 5.1.6. Irregular
 - 5.1.7. Interacting
 - 5.1.8. Gravitationally Lensed
 - 5.2. [Size]
 - 5.2.1. Giant
 - 5.2.2. Dwarf
 - 5.3. [Activity]
 - 5.3.1. Normal
 - 5.3.2. AGN
 - 5.3.2.1. Quasar
 - 5.3.2.2. Seyfert
 - 5.3.2.3. Blazar
 - 5.3.2.4. Liner
 - 5.3.3. Starburst
 - 5.3.4. Ultraluminous
 - 5.4. [Component]
 - 5.4.1. Bulge
 - 5.4.2. Bar
 - 5.4.3. Disk
 - 5.4.4. Halo
 - 5.4.5. Ring
 - 5.4.6. Central Black Hole
 - 5.4.7. Spiral Arm
 - 5.4.8. Dust Lane
 - 5.4.9. Center/Core
 - 5.5. [Grouping]
 - 5.5.1. Pair
 - 5.5.2. Multiple
 - 5.5.3. Cluster
 - 5.5.4. Supercluster
- 6. Cosmology
 - 6.1. [Morphology]
 - 6.1.1. Deep Field
 - 6.1.2. Large-Scale Structure
 - 6.1.3. Cosmic Background
 - 6.2. [Phenomenon]
 - 6.2.1. Lensing
 - 6.2.2. Gamma Ray Burst
 - 6.2.3. Dark Matter
- 7. Sky Phenomenon
 - 7.1. Night Sky
 - 7.1.1. Constellation
 - 7.1.2. Asterism
 - 7.1.3. Milky Way
 - 7.1.4. Trail
 - 7.1.4.1. Meteor
 - 7.1.4.2. Star
 - 7.1.4.3. Satellite
 - 7.1.5. Zodiacal Light
 - 7.1.5.1. Gegenschein

Astronomy Visualization Metadata (AVM) Standard - **Version 1.1**

- 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
 - 8.1.4. Detector
 - 8.2. Spacecraft
 - 8.2.1. Orbiter
 - 8.2.2. Probe
 - 8.2.3. Lander
 - 8.2.4. Manned
 - 8.2.5. Launch Vehicle
- 9. People
 - 9.1. Scientist
 - 9.2. Astronaut
 - 9.3. Other/General

4.2 Type

This tag identifies the specific type of image indicating its origin.

The AVM tags specifically encompass the requirements of public-friendly and print-ready images derived from astronomical datasets. However, artist conceptions, illustrations, image collages, and diagrams can also make use of the standard. The **Type** tag identifies the nature of the image. The values for this tag are:

- **Observation** – An astronomical image rendered from telescopic data.
- **Artwork** – Artists' renderings of astronomical phenomena or objects.
- **Photographic** – Photos from film/digital cameras.
- **Planetary** – Images from planetary orbiters/landers.
- **Simulation** – Digital renderings of simulated/computed datasets.
- **Chart** – A graph or diagram based on data
- **Collage** – Any image that has multiple elements and/or image types.

The CREATOR, CONTENT, PUBLISHER, and FILE Metadata sections of the AVM apply to any image type. The OBSERVATION and COORDINATE sections apply primarily to **Types Observation and Planetary**.

Any astronomical image originating from telescopic data should be categorized as *Observation*. This could either represent digital FITS data rendered into an image, or photographic plates/film exposed in a telescope.

Artwork covers any kind of illustration or drawing, including diagrams or schematics used to explain science concepts.

Photographic images ultimately originate from a camera, though in principle they could include sky photos (star trails, wide angle time exposures, meteor trails, etc.) as well as other general astronomical subject matter (photos of telescopes, observatories, etc.). These images will not include COORDINATE tags.

Planetary images are included to encompass any imagery originating from remote exploration missions, including orbiters and landers. These images will not contain WCS coordinates (it would generally be irrelevant) though future expansions to this metadata definition may allow inclusion of appropriate latitude/longitude identification instead.

Chart includes any data presentation that is not an image. This commonly includes spectra, graphs of observationally derived data, and star charts based on positions of objects. The *Chart* type should be used if the data are the primary focus, even if it has been visually enhanced with annotations for clarity.

Collage is a special **Type** to address layouts that incorporate multiple images that may be of any combination of types. The OBSERVATION and COORDINATE sections should not be used for *Collage* types even if one or more elements are OBSERVATION because of the ambiguity in associating the information with the correct portion of the layout. The AVM **Description** tag should contain details about the collage elements including observational details as appropriate. It is

very good practice to offer every element of a *Collage* layout as an individually tagged image file as well.

4.3 *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 artifacts, but still acceptable for reference.

Good images are ones typically rendered from data by hand for the best visual impact. The *Moderate* designation applies if the source dataset has some cosmetic artifacts that have not been cleaned up, or if the image was rendered automatically in a batch process. If the dataset has significant artifacts, including background gradients or extensive artifacts, or it is the product of batch processing of only moderate quality, it should be flagged as *Poor*.

4.4 *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** – single-channel image
- **Pseudocolor** – single channel image, color mapped to intensity

4.5 *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*:

<u>Spectral.Band</u>	<u>Represents</u>
Radio	$\lambda \geq 10 \text{ mm}$ $\nu \leq 30 \text{ GHz}$
Millimeter	$0.1 \text{ mm} \leq \lambda \leq 10 \text{ mm}$ $3000 \text{ GHz} \geq \nu \geq 30 \text{ GHz}$
Infrared	$1 \mu \leq \lambda \leq 100 \mu$
Optical	$0.3 \mu \leq \lambda \leq 1 \mu$ $300 \text{ nm} \leq \lambda \leq 1000 \text{ nm}$ $3000 \text{ \AA} \leq \lambda \leq 10000 \text{ \AA}$
Ultraviolet	$0.01 \mu \leq \lambda \leq 0.3 \mu$ $100 \text{ \AA} \leq \lambda \leq 3000 \text{ \AA}$

X-ray	$1.2 \text{ eV} \leq E \leq 120 \text{ eV}$ $0.1 \text{ \AA} \leq \lambda \leq 100 \text{ \AA}$
Gamma-ray	$0.12 \text{ keV} \leq E \leq 120 \text{ keV}$ $E \geq 120 \text{ keV}$

4.6 *Spatial.CoordinateFrame*

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

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

4.7 *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)
- **CEA** – cylindrical equal-area

4.8 *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 included WCS info is to be taken as approximate or incomplete.

4.9 *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. Of these formats, PDF may be used to include editable, resolution-independent vector-based graphics.

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

5 Appendix B: Abbreviations

AVM	Astronomical Visualization Metadata
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
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)
LO	List-ordered
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)
VO	Virtual Observatory
WCS	World Coordinate System
XMP	Extensible Metadata Platform

6 Appendix C: WCS Representation in AVM

The World Coordinate System, or WCS, is a standard for mapping pixels in a rectilinear image into coordinate positions on a sphere. In astronomy, this is the celestial sphere, but the math is basically the same as for handling map projections on Earth. Since spheres are round and rectangles are flat one must of necessity distort the spherical coordinates when projecting onto a rectilinear geometry.

The AVM incorporates terms for WCS representation of astronomical observations for several reasons. Coordinate information can be used as search criteria for imagery based on position or field of view. It can provide basic educational information about an image (location, orientation, constellation, etc.). Most interestingly, advanced imaging applications can use the WCS metadata to render the image in its correct location in the sky.

The structure of this appendix is three-fold. First it defines the basic terms and concepts of WCS representation. Second, it establishes the conventions and terms used to describe WCS mappings in AVM. Third, it provides mappings between the AVM tags and FITS WCS representations.

It should be noted that WCS representations in AVM represent a simplified subset of the more general possibilities in FITS datasets. While the latter covers a broad variety of instrument data formats and allows for research-quality sub-pixel accuracy for astrometry, the audience and goals of AVM are more general. Adopting a simpler standard (similar to early WCS FITS implementations) makes it more accessible to a less technical EPO audience while meeting the needs of qualitatively correct handling of sky projections.

The emphasis on the AVM WCS representation is on simplicity and terms that are more meaningful to users. A certain amount of hands-on evaluation of tags is inevitable when developing workflows to recover the WCS information for high-quality outreach imagery. Sacrificing some of the highest-order refinements in the FITS standards in exchange for meaningful terminology has proven useful at this stage of standards development and met with general approval from the astronomy visualization community. Though by some standards this astrometry may not be considered research-level, this is not a target goal of AVM. Research should always be conducted with source observation data, not public-ready print-friendly derivative products!

As the needs and applications arise, the AVM WCS standards may evolve over time to encompass more advanced representations, just as the FITS standard has evolved over time. Future developments may include coordinate matrix representations and distortion correction terms.

6.1 WCS Basics and Terminology

Any WCS representation of celestial images is defined by several basic parameters. These allow, through the proper math and software libraries, the unambiguous interpretation of where every pixel in an image will fall on the sky.

This enables, for instance, programs to render an image in a sky dome in the proper scale and orientation with images and cataloged positions of sources.

6.1.1 Projection

The image projection defines how one maps between a curved spherical surface and a flat rectangular grid. There are many dozens of projections used in cartography ranging from the familiar to the bizarre. Several common examples are described below.

One of the most common for rendering small areas of sky is the “Tangent” (TAN) projection, which is a good approximation of how a camera works. The spherical coordinates map onto the flat grid following a line projected from the center through the sphere, through a point on its surface, on to the corresponding position of the flat grid that touches the outside the sphere (at a tangent) at a given reference position. A “Sinusoidal” (SIN) projection is closely related, and numerically indistinguishable for small fields of view.

A “Cartesian” (CAR) projection (more properly: “Plate-Carrée”) is one for which the x , y image coordinates correspond linearly to degree measurements in the sky. This is mathematically one of the simplest possible projections, but carries with it the cost of massively increasing distortion towards the pole. It is useful, however, when incorporating all-sky images as skydome environments in general 3D graphics packages (such images can be applied to a sphere using a “spherical” projection algorithm). A “Cylindrical Equal Area” (CEA) projection is similar but compensates for the polar distortion.

The related AVM tag is **Spatial.CoordsystemProjection**.

6.1.2 Coordinate System

The coordinate system refers to the orientation and units of the angular divisions on the coordinate sphere, as in latitude and longitude on a globe. Two of the most common are “celestial” (referenced to the Earth’s axis of rotation) and “galactic” (aligned with the plane of the Milky Way with the Galactic Center at its origin).

Celestial coordinates come in several flavors due to the ongoing precession of the Earth’s rotational axis. FK4 is an older system referenced to B1950 precession while FK5 is the current J2000 epoch. Both systems may require an additional Equinox term defining the actual epoch of observation if it is not the default reference year.

The ICRS celestial system is referenced to a cosmological background grid at a J2000 epoch and does not include an equinox term. Galactic coordinates likewise specify no epoch as they are referenced to the Milky Way center.

The related AVM tags are **Spatial.CoordinateFrame**, **Spatial.Equinox**.

6.1.3 Reference Position

Regardless of projection, a single position in the image must be tied to a corresponding sky position in the specified reference frame. This is done by specifying a reference pixel in the image and defining the exact map coordinate

to which it corresponds. Note the reference pixel does not have to be an integer; fractional values can identify a specific location within a pixel. The pixel center is considered to be the origin of the pixel.

The related AVM tags are **Spatial.ReferenceValue**, **Spatial.ReferencePixel**, and **Spatial.ReferenceDimension**.

6.1.4 Scale and Orientation

The scale of the pixels (e.g. number of degrees per pixel at the reference position) defines the overall coverage of the image. Note that the actual pixel scale may vary across the image as a function of the projection employed. The orientation of the image with respect to the reference coordinate grid (at the reference position) must also be specified since the image columns may not be aligned with sky “north.” Rotation is defined to be positive in the “east of north” sense. For typical sky projections this means a positively rotated reference axis is rotated in the counterclockwise direction.

The related AVM tags are **Spatial.Scale** and **Spatial.Rotation**.

6.1.5 Additional Distortions

Often an image is not in fact a perfect representation of the specified projection. For instance, distortions in the optics can lead to complex distortion patterns in the final image. While distortion can be present at virtually any image scale due to optics and processing issues, they are particularly significant at wider fields of view, particularly with wide-angle sky photography using traditional camera lenses.

Distortion can be expressed in terms of skew (if the coordinate axes are not at right angles to one another) as well as other kinds of polynomial corrections. Some software is able to interpret these corrections to yield more accurate coordinates and image displays.

The current 1.1 implementation of AVM does not incorporate distortion correction terms, though it does optionally allow source FITS header information to be stored for more advanced applications. As the need arises, future versions of the AVM may be expanded to encompass a larger superset of geometric distortion terms. Note that the **Spatial.CDMatrix** term from AVM 1.0 has been deprecated in 1.1 since skew terms should not exist in outreach-ready imagery.

The related AVM Tags are **Spatial.CDMatrix** and **Spatial.FITSheader**.

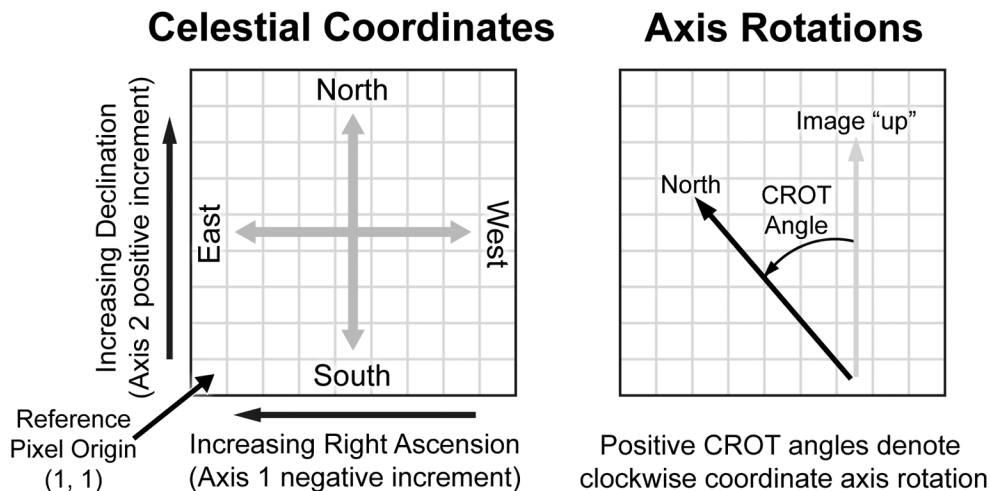
6.2 WCS Representation in AVM

WCS projections in AVM are described relative to a regular Cartesian grid referenced to the image as it is displayed. The differences between this convention and the more generalized byte-ordered convention in the FITS standard will be detailed in subsequent sections.

The AVM WCS tags default to a simple way of describing WCS data that are physically meaningful to the human eye. The **Spatial.Scale** term can allow for roughly calibrated angular measurements across an image, for instance, to compute the approximate field of view of a rectangular image.

6.2.1 AVM WCS Conventions

Typical astronomical images for the public are most commonly rendered as they would appear to a viewer looking outward at the sky. The figure below illustrates the AVM convention for a celestial projection system in which the angular positions are measured in Right Ascension (equivalent to longitude) and Declination (equivalent to latitude).



Note that East and West directions are flipped with respect to traditional terrestrial map displays. This flip is a consequence of viewing the celestial sphere from the inside, as opposed to viewing a terrestrial sphere from the outside. As a result, the increment of the Right Ascension axis is taken to be a negative measure since it decreases as you move right, away from the origin.

Rotations of the celestial coordinate grid with respect to the image display are measured eastward of North (“up”). As shown in the figure above, a positive rotation corresponds to a counterclockwise rotation of the *North* axis with respect to the image. This rotation is measured at the position of the reference pixel in the image. Thus if an image has a rotation angle of +45 degrees (as pictured above), rotating the entire *image* clockwise by 45 degrees will align its north axis with the “up” direction.

The origin pixel of the image is defined as pixel (1, 1) in the lower left corner. This follows FITS conventions for pixel identification but is different from many programming conventions in which the first index element starts at (0, 0). Moreover, this AVM convention follows traditional conventions of geometry for axis origins, but does not match the row orderings of data within common image formats. All standard image display standards (GIF, PNG, TIFF, JPEG) paint images from the top row down. Therefore, many generic image display programs will number pixels starting with (0, 0) at the top left corner, and images may be represented internally as arrays in the same manner.

Note that, following the historical roots of the FITS convention, the index of a pixel is referenced to its center. Thus the lower left, center, and upper right subpositions within, for example, the origin pixel correspond to the non-intuitive coordinates of (0.5, 0.5), (1, 1), and (1.5, 1.5).

6.2.2 Image Parity

It is standard, and preferable, to display images as they would appear on the sky as viewed from Earth. However, it is possible that some images may be inverted, or mirror-imaged from this orientation. In this case, East is to the right of North, as is typical of terrestrial map projections. The term “parity” can be used to differentiate between the two possible image reflections. The traditional sky view will be defined as a negative parity (with a negative increment along the x-axis), while the horizontally mirrored equivalent will be defined as positive parity. It is strongly preferred for astronomy imagery to be rendered as negative parity, but AVM does allow for positive parity representation as well.

In the AVM standard, the sign of the **Spatial.Scale[1]** term equivalently identifies the image parity. The **Spatial.Scale[2]** term should always be positive.

6.2.3 CDMatrix Representations

Modern WCS implementations have abandoned the more human-understandable scale and rotation terms in favor of a more generalized “CD matrix”. The four elements in the CD matrix can encode scales along each axis as well as independent rotations of each coordinate axis (representing “skew” of an image). Practically speaking for rendered outreach imagery, this additional flexibility is generally unnecessary since final reduced images should be rectilinear.

The **Spatial.CDMatrix** tag was an optional (though redundant) element in AVM 1.0, but has been deprecated in this 1.1 standard. However the CD matrix terms may be useful to compute in instances where software is expecting these terms instead of scales and rotations. It may also be necessary to compute **Spatial.Scale** and **Spatial.Rotation** from 1.0 version images. In the common simplified case where the coordinate axes are orthogonal the scale/rotation and CD matrix terms may be calculated quickly from one another.

Note that the inverse tangent function referenced in this document assumes arguments in the (x, y) ordering: $\text{atan2}(x, y)$. C++ defines this function with the reverse order (y, x) and the ordering of elements in this document needs to be adjusted accordingly for this code convention.

Deriving CDMatrix from Scale/Rotation

Note in this section that the **Spatial.*** tag has been abbreviated to the form **S.*** for clarity.

In the absence of distortion effects, a CDMatrix that fully describes a simple scale and rotation can be derived easily:

$$S.CDMatrix \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} = \begin{pmatrix} S.Scale[1] \cdot \cos(S.Rotation) & -S.Scale[2] \cdot \sin(S.Rotation) \\ S.Scale[1] \cdot \sin(S.Rotation) & S.Scale[2] \cdot \cos(S.Rotation) \end{pmatrix}$$

Deriving Scale/Rotation from CDMatrix:

In the simplest scenarios where the x and y axis scales are of the same magnitude, the rotation angle is easily recovered from the CDMatrix elements:

$$S.Rotation = \arctan2(S.CDMatrix[4], -S.CDMatrix[2])$$

The scale values follow naturally from the determinant of the CD matrix:

$$\det(S.CDMatrix) \equiv |S.CDMatrix| = [1] \cdot [4] - [2] \cdot [3]$$

$$S.Scale[1] = \sqrt{|S.CDMatrix|} \cdot \text{sign}(|S.CDMatrix|)$$

$$S.Scale[2] = \sqrt{|S.CDMatrix|}$$

Note that the sign of the determinant defines the image parity, and is used to assign the sign of the **Spatial.Scale[1]** term.

These conversions from a CDMatrix assume an orthogonal coordinate system without skew and with equal scale magnitudes on both axes. To validate this assumption, one may diagnostically compute independent rotation and scale values following the equations in section 6.3.3; if the values match then the system is orthogonal. If not the source image should be re-rendered in an AVM-valid orthogonal manner.

6.2.4 AVM WCS and Rescaled Images

Final display images are often offered in multiple resolutions, particularly if the full image is exceptionally large. As a shortcut to AVM providers, the WCS solution does not have to be re-derived for each version of the image. Instead, the supplied WCS solution should be interpreted in the context of the original image dimensions for which it was determined. These are encoded in **Spatial.ReferenceDimension**.

If the image has been proportionally rescaled (but not otherwise cropped, rotated, or flipped) then the old solution can equally apply to the new image dimensions.

$$\text{RATIO} = (\text{current dimension})/(\text{ReferenceDimension})$$

$$\text{Rescaled ReferencePixel}[1, 2] = \text{Spatial.ReferencePixel}[1, 2] * \text{RATIO}$$

$$\text{Rescaled Scale}[1, 2] = \text{Spatial.Scale}[1, 2]/\text{RATIO}$$

Note that the x and y scales may not be exactly equal due to round off issues, but they should be so close that using either x or y ratios should give a solution to within a pixel.

Software using AVM WCS should always perform the comparison between the actual image dimension and the **Spatial.ReferenceDimension**. As an additional sanity check, it is possible to compare the x and y ratios and reject the WCS solution if they are significantly different (more than 1-2% difference).

6.2.5 FITS Headers and Distortion Correction Terms

The FITS standard includes a variety of techniques for expressing distortions in the image beyond the idealized projections. These may compensate for irregularities in optics or data processing once the final image data are recorded and can allow for much more accurate registration of images against the sky.

Such terms are currently beyond the scope of AVM version 1.1. However, the **Spatial.FITSheader** tag does allow the full FITS WCS keyword list to be tagged to the file. This may be used in later versions of AVM to reconstruct distortion terms, or may be useful for developers using code to parse FITS headers directly. Note, however, that there are significant ambiguities in how a FITS image can be rendered into an image. This can result in orientation errors when trying to use a source FITS header with a rendered image, unless that FITS header was derived specifically for the rendered image itself.

6.3 AVM–FITS Conversions

The WCS terms in the FITS and AVM standards are closely related, but AVM represents a simplified subset of the many possible representations in FITS. This section outlines how to obtain AVM terms from FITS headers, which are the most common source of WCS information.

6.3.1 Data Descriptor vs. Image Format

The FITS file format is not an image format per se, but a completely generalized method of describing arrays of information. “Axes” within FITS files may refer to spatial coordinates, wavelengths, velocities, or any desired data format.

As a result there is no default convention for displaying the array elements of a FITS file as an image without referencing the WCS data. Different display/analysis applications have different conventions, so the same FITS file may appear different on-screen in different applications. This is very different from standard image formats (JPEG, TIFF, PNG, etc.) in which the display convention is standardized; the first bytes of the file correspond to the upper left of the displayed image which is filled in left to right, top to bottom.

For FITS image files, the WCS information *defines* where each pixel should be placed when viewed as an image. WCS-compliant applications will therefore render these images as seen on the sky, regardless of orientation or ordering of the axes. This often results in rectangular images that are rotated on-screen.

When FITS data are rendered into images, the default is to map the array elements into a standard rectangular picture grid and save it as a standard image format. This may be done in many ways. Some analysis packages allow for screen dumps, a variety of image processing programs and command line utilities include limited FITS support. The *FITS Liberator* plug-in is widely used for Photoshop workflows.

The process of rendering the FITS data into an image file can easily result in ambiguity in how the FITS WCS keyword values should be interpreted with respect to what is seen on-screen. This interpretation depends on the way the FITS data are ordered and what conventions the rendering software utilized. In addition, if the image is further cropped, rotated, and/or rescaled, the original WCS solution becomes invalid (though if the process is documented it is possible to derive a new WCS solution from the original).

Because of these complexities, there is no “magic bullet” formula for getting a correct solution from a source FITS header. The possibility of parity flips or

rotations always exists, and it means that ultimately any workflow for obtaining AVM WCS tags will require experimentation and validation.

If the image rendering process is documented, then these WCS ambiguities can be minimized. The notes in this section are designed to outline the basics of deriving AVM tags from associated FITS headers with the above caveats in mind.

6.3.2 Mapping AVM Tags and FITS Keywords

If an AVM-tagged image has an associated FITS header, either from a source file or independently derived from another source (like *astrometry.net*), the AVM tags may be populated directly from the corresponding FITS keywords.

However, because AVM-tagged images have an established display convention, some reordering of indices is necessary for some FITS WCS setups. It may take some experimentation to derive correct workflows for specific FITS header types, but these guidelines should provide a solid start.

The general mappings are as follows though there are possible parity issues that will affect the signs of some elements (this is discussed at greater length below):

Spatial.CoordsystemProjection = final 3 characters of CTYPE1 or CTYPE2 (should be identical)

Spatial.CoordinateFrame = RADECSYS

Spatial.Equinox = EQUINOX

Spatial.ReferenceValue[1, 2] = [CRVAL1, CRVAL2]

Spatial.ReferencePixel[1, 2] = [CRPIX1, CRPIX2]

Spatial.ReferenceDimension[1, 2] = [NAXIS1, NAXIS2]

Spatial.Scale[1, 2] = [CDELTA1, CDELTA2]

Spatial.Rotation = CROTA2

Spatial.CDMatrix[1, 2, 3, 4] = [CD1_1, CD1_2, CD2_1, CD2_2]

Note that **Spatial.CDMatrix** is deprecated in AVM 1.1 but is included to accommodate images tagged with the 1.0 specifications. It is advised that this tag should be empty for 1.1 compliant images.

6.3.3 CDELTA, CROT, and CD Matrix Values

Older FITS standards utilized axis scales (CDELTA1, CDELTA2) and rotations (CROTA2) as have been adopted for the AVM standard. They have the advantage of being easily interpreted by eye (scales are in degrees per pixel, rotation is measured eastward of north). However, in the modern FITS specification, these have been dropped in favor of a matrix format.

If the FITS header contains CD matrix elements but not the CROTA2 and CDELTA terms, then these terms must be derived from the CD matrix to use the AVM mappings in the previous section.

The scale values follow naturally from the determinant of the CD matrix:

$$\det(CD) = |CD| = CD1_1 \cdot CD2_2 - CD1_2 \cdot CD2_1$$

$$CDELTA1 = \sqrt{|CD|} \cdot \text{sign}(|CD|)$$

$$CDELTA2 = \sqrt{|CD|}$$

The rotation likewise follows (note that here the *arctan2* function uses the (x, y) ordering of its arguments).

$$CROTA2 = \text{arctan2}(CD2_2, -CD1_2)$$

The reverse transformation to the CD matrix is:

$$\begin{pmatrix} CD1_1 & CD1_2 \\ CD2_1 & CD2_2 \end{pmatrix} = \begin{pmatrix} CDELTA1 \cdot \cos(CROT) & -CDELTA2 \cdot \sin(CROT) \\ CDELTA1 \cdot \sin(CROT) & CDELTA2 \cdot \cos(CROT) \end{pmatrix}$$

These conversions assume the CD matrix represents an orthogonal coordinate system with scales identical in magnitude (but not necessarily sign) along both axes. This is the desired format for valid AVM spatial tags.

If there is concern that these conditions have not been met in a source FITS file it is possible to calculate scale and rotation terms independently. Comparing the magnitude of these two values gives a measure of the robustness of the solution; if they disagree by more than a tiny fraction then the image contains undesired stretch or skew.

$$CDELTA1 = \sqrt{CD1_1^2 + CD2_1^2} \cdot \text{sign}(|CD|)$$

$$CDELTA2 = \sqrt{CD1_2^2 + CD2_2^2}$$

If the independently-derived rotations defined below are close but not identical, the average gives a good intermediate value.

$$CROTA2(a) = \begin{cases} \text{arctan2}(CD1_1, CD2_1) & [CD1_1 \cdot CD2_2 > 0] \\ \text{arctan2}(-CD1_1, -CD2_1) & [CD1_1 \cdot CD2_2 \leq 0] \end{cases}$$

$$CROTA2(b) = \text{arctan2}(CD2_2, -CD1_2)$$

$$CROTA2 = \text{avg}(CROTA2(a), CROTA2(b))$$

6.3.4 FITS Image Parity and AVM Tags

Some variations are possible in the mappings depending on the image parity of the source FITS image. Similarly to the process described above for AVM WCS, the FITS image parity can be derived from either the CDELTA or CD values.

Using the CDELTA values, the parity is simply the sign of the product of CDELTA1 and CDELTA2. The sign of the determinant of the CD matrix ($CD1_1 \cdot CD2_2 - CD1_2 \cdot CD2_1$) equivalently defines the parity of a FITS image.

In most cases, the mapping between AVM and FITS is straightforward, but it may require a reordering of the y axis reference pixel. If the source FITS file has a negative parity, but the image has been correctly rendered to display East to the left (counterclockwise from North), then the mappings shown above are correct.

If the source FITS file is positive parity, but is displayed in a negative parity (with East to the left), then the following reordering is necessary:

Spatial.ReferencePixel[2] = NAXIS2 – CRPIX2

Spatial.Scale[1] = –CDELTA1

Spatial.Rotation = CROTA2 +/- 180 (whichever falls between -180 & +180)

Spatial.CDMatrix[1, 2, 3, 4] = [CD1_1, –CD1_2, CD2_1, –CD2_2]

Some variations are possible depending on the image parity of the source FITS image. The process is further complicated if the image has been rotated or cropped with respect to the source FITS file. It is straightforward to track such changes in the **Spatial.Scale** and **Spatial.Rotation** terms, but it is important to validate any such derived solution for accuracy using an AVM-compliant image display program (this is currently possible using Microsoft's World Wide Telescope).

Also note that in the AVM convention it is proper to maintain the sign convention that **Spatial.Scale**[2] is always positive, with the sign of **Spatial.Scale**[1] reflecting the image parity. If CDELTA2 is negative, then it is also necessary to invert the sign of both **Spatial.Scale** terms and compensate by offsetting the rotation by 180 degrees.

Spatial.Scale[1, 2] = [–CDELTA1, –CDELTA2]

Spatial.Rotation = CROTA2 +/- 180

6.3.5 Constructing a FITS Header from AVM Tags

If an AVM-tagged image is to be used by a software application that can handle FITS files, it is easily possible to reverse-engineer a FITS header from the AVM tags following the formula above.

The only catch has to do with the ordering of the rows in an equivalent FITS file. The AVM convention when mapped onto a FITS header describes a data file in which the rows are displayed from the bottom up. However, the common image formats actually represent images from the top row down.

An easy solution is to simply reverse the row ordering of the lines in the image file (equivalent to vertically flipping the image). The FITS header keywords recovered from the AVM tags will accurately describe the image data.

6.4 Other Information

6.4.1 Best Practices for AVM WCS Implementations

There are a number of practices that any public-friendly and AVM-friendly astronomical imagery should follow.

- Orient images as they would be viewed in the sky (negative parity). This means following the “East is left of North” convention where the x scale is negative and the y scale is positive.
- Verify WCS tagging using sky display tools (as available). Making sure the coordinates look right to you goes a long way towards assuring they will work for everyone.

- Some WCS is better than none. Even if an image does not have a well-derived WCS solution, including what is known can be helpful even if it is just a center coordinate or a pixel scale. There is a **Spatial.Quality** tag for indicating the level of the solution.

6.4.2 WCS Notes for Developers

For applications to be fully compliant with AVM WCS they should meet the following requirements.

- Be able to utilize either Scale/Rotation and/or CDMatrix values, depending on which is present.
- Reference any image arrays starting with pixel (1,1) at the lower left corner, running (X_{max} , Y_{max}) at the upper right.
- Look for images that have been proportionally rescaled from the stated **Spatial.ReferenceDimension** values and scale the WCS appropriately
- Prepare to identify supported coordinate systems/projections and act on them as appropriate; do not assume everything is, for instance, celestial coordinates at the 2000 epoch.

6.4.3 WCS FAQ

Why was the CDMatrix representation in AVM 1.0 dropped from the 1.1 standard?

Community input on the topic of simplicity vs. full support of FITS terms was varied, but a general consensus was clear that, at this early stage of the standard, the simplicity of a scale/rotation representation outweighed the marginal returns of the CD matrix. Moreover, having two redundant representations of the same information could easily result in inconsistent information if one set of terms was not updated in tandem with the other terms. The only additional information that a CD matrix can encode is skew, but a public-friendly outreach image should, by definition, not be skewed. The FITS standard functioned for decades without the CD matrix terms, and even today researchers commonly omit it from their own custom code for convenience.

Why not include distortion corrections?

There are at least three major conventions for representing distortion corrections, and probably many more developed for special purposes. The complexity involved in digesting all possible systems to a reasonable subset for AVM was simply beyond the scope of this project at this time. As more software begins implementing AVM compatibility and the need and support arises for distortion terms they can be incorporated into future AVM revisions.

Why not just use FITS headers for WCS?

The incredible flexibility of WCS expression in FITS leads to a nightmarish complexity that is beyond the scope of the general outreach community. That, combined with the intrinsic ambiguities on how data are mapped

from FITS to image formats with well-established display conventions would make the process difficult to manage for anyone not deeply immersed in FITS conventions. For those wanting access to FITS header information for their own purposes, however, there is now a tag for including the full FITS header.

Why not include four-corner coordinates?

Rectilinear images can be spatially defined by including the coordinates of their four corners, and this representation has some advantages for searches determining if a specific position falls within an image. However, this information is fully derivable from the WCS projection information, and in some projection types is undefined. Since AVM allows for various coordinate systems (e.g. celestial, galactic), including four-corner coordinates would not help simplify search engine type searches since the coordinates would still have to be parsed and reinterpreted to a common reference system. In that case it is just as easy to start with the WCS representation and calculate the corners if desired.

6.4.4 WCS References

The primary reference for WCS in FITS is:

M. R. Calabretta & E. W. Greisen, "Representations of Celestial Coordinates in FITS" (2002) *Astronomy & Astrophysics*, 395, 1077-1122.

The home site for the FITS standard is at:

<http://fits.gsfc.nasa.gov/>

7 Appendix D: XMP Access and Examples

7.1 XMP Programming Access

AVM tags may be accessed by custom software. The tags are stored in the image header blocks as text preceding the image data. Custom code can easily be written to parse this text block to identify and extract the AVM tags based on the surrounding XMP syntax.

There are also tools and libraries available to aid in XMP access. Some available tools (at the time of this document) include the following.

Adobe XMP Software Developer's Kit. This contains code usable on Macintosh, Windows, and UNIX platforms. The Adobe XMP SDK can be downloaded from:

<http://www.adobe.com/devnet/xmp/>

<http://partners.adobe.com/public/developer/xmp/sdk/>

Other third party XMP solutions are under development. One example is the command line ExifTool that may be helpful for accessing AVM metadata.

<http://www.sno.phy.queensu.ca/~phil/exiftool/>

7.2 XMP List Formats

XMP headers represent list-type values as a series of nested tags. Each list element is contained within delimiters, while the entire set of tags is contained within one of two types of delimiters that define the structure of the list.

If the elements in the list are considered to be unordered and are equally meaningful in any sequence then they are identified as a “bag” sequence. The corresponding delimiters are <Bag></Bag>. In AVM, these correspond to any tag of type “list.”

For lists in which the element orders are significant, the corresponding XMP identifier is “Seq” or “Sequential.” These lists will be marked by <Seq></Seq> delimiters. These are used for any AVM tag of type “list(2)” or “list(s)”.

7.3 XMP Reference Header File

A sample XMP file listing provided here demonstrates the internal syntax of this file format. The content of each tag is an all-caps version of the tag name to allow for the bracketing syntax. Non-AVM tags have been deleted for clarity.

This XMP metadata may typically be located within an image file by accessing the header bytes of the image. If no XMP/XML libraries are used, AVM tags may still be read by parsing the header text stream directly; the format is simple enough to allow for simple custom code to do the job.

```
<x:xmpmeta xmlns:x="adobe:ns:meta" x:xmp:tk="Adobe XMP Core 4.1-c036 46.276720, Mon Feb 19 2007 22:13:43
">
  <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
    <rdf:Description rdf:about=""
      xmlns:dc="http://purl.org/dc/elements/1.1/">
      <dc:format>application/vnd.adobe.photoshop</dc:format>
```

Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

```
<dc:creator>
  <rdf:Seq>
    <rdf:li>CONTACT.NAME</rdf:li>
  </rdf:Seq>
</dc:creator>
<dc:title>
  <rdf:Alt>
    <rdf:li xml:lang="x-default">TITLE</rdf:li>
  </rdf:Alt>
</dc:title>
<dc:description>
  <rdf:Alt>
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  </rdf:Alt>
</dc:description>
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  </rdf:Bag>
</dc:subject>
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  <photoshop:ICCProfile>Adobe RGB (1998)</photoshop:ICCProfile>
  <photoshop:Source>CREATOR</photoshop:Source>
  <photoshop:Headline>HEADLINE</photoshop:Headline>
  <photoshop:Credit>CREDIT</photoshop:Credit>
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  <photoshop:History/>
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  <avm:ReferenceURL>REFERENCEURL</avm:ReferenceURL>
  <avm:Type>TYPE</avm:Type>
  <avm:Image.ProductQuality>IMAGE.PRODUCTQUALITY</avm:Image.ProductQuality>
  <avm:ID>ID</avm:ID>
  <avm:Spatial.CoordinateFrame>SPATIAL.COORDINATEFRAME</avm:Spatial.CoordinateFrame>
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  <avm:ResourceID>RESOURCEID</avm:ResourceID>
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  <avm:MetadataDate>METADATADATE</avm:MetadataDate>
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```

Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

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<avm:Spectral.CentralWavelength>
  <rdf:Seq>
    <rdf:li>SPECTRAL.CENTRALWAVELENGTH</rdf:li>
  </rdf:Seq>
</avm:Spectral.CentralWavelength>
<avm:Spectral.Notes>
  <rdf:Alt>
    <rdf:li xml:lang="x-default">SPECTRAL.NOTES</rdf:li>
  </rdf:Alt>
</avm:Spectral.Notes>
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  </rdf:Seq>
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  </rdf:Alt>
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  </rdf:Alt>
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  </rdf:Seq>
</avm:Spatial.CDMatrix>
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    <rdf:li>RELATEDRESOURCES</rdf:li>
  </rdf:Bag>
</avm:RelatedResources>
```


Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

```
<avm:Distance>
  <rdf:Seq>
    <rdf:li>DISTANCE_LY</rdf:li>
    <rdf:li>DISTANCE_Z</rdf:li>
  </rdf:Seq>
</avm:Distance>
</rdf:Description>
<rdf:Description rdf:about=""
  xmlns:lptc4xmpCore="http://iptc.org/std/lptc4xmpCore/1.0/xmlns/">
  <lptc4xmpCore:CreatorContactInfo rdf:parseType="Resource">
    <lptc4xmpCore:CiEmailWork>CONTACT.EMAIL</lptc4xmpCore:CiEmailWork>
    <lptc4xmpCore:CiTelWork>CONTACT.TELEPHONE</lptc4xmpCore:CiTelWork>
    <lptc4xmpCore:CiAdrExtadr>CONTACT.ADDRESS</lptc4xmpCore:CiAdrExtadr>
    <lptc4xmpCore:CiAdrCity>CONTACT.CITY</lptc4xmpCore:CiAdrCity>
    <lptc4xmpCore:CiAdrRegion>CONTACT.STATEPROVINCE</lptc4xmpCore:CiAdrRegion>
    <lptc4xmpCore:CiAdrPcode>CONTACT.POSTALCODE</lptc4xmpCore:CiAdrPcode>
    <lptc4xmpCore:CiAdrCtry>CONTACT.COUNTRY</lptc4xmpCore:CiAdrCtry>
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  </lptc4xmpCore:CreatorContactInfo>
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  xmlns:xapRights="http://ns.adobe.com/xap/1.0/rights/">
  <xapRights:UsageTerms>
    <rdf:Alt>
      <rdf:li xml:lang="x-default">RIGHTS</rdf:li>
    </rdf:Alt>
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</x:xmpmeta>
```

7.4 XMP Reference Compact JPEG Header File

Adobe Photoshop CS3 introduced a compact header variant for XMP tags. In these the bracketing XMP descriptors (e.g. <avm:Type>TYPE</avm:Type>) have been replaced with a shortened format (avm:Type="TYPE"). Tags that have nested descriptors (as with lists) are unchanged. In addition, the formatting white space has been deleted. A corresponding version of the sample compact format follows.

```
<x:xmpmeta xmlns:x="adobe:ns:meta/" x:xmpptk="Adobe XMP Core 4.1-c036 46.276720, Mon Feb 19 2007 22:13:43
"> <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"> <rdf:Description rdf:about=""
xmlns:dc="http://purl.org/dc/elements/1.1/" xmlns:xap="http://ns.adobe.com/xap/1.0/"
xmlns:xapMM="http://ns.adobe.com/xap/1.0/mm/" xmlns:stRef="http://ns.adobe.com/xap/1.0/sType/ResourceRef#"
xmlns:photoshop="http://ns.adobe.com/photoshop/1.0/" xmlns:avm="http://www.communicatingastronomy.org/avm/1.0/"
xmlns:illustrator="http://ns.adobe.com/illustrator/1.0/" xmlns:tiff="http://ns.adobe.com/tiff/1.0/"
xmlns:exif="http://ns.adobe.com/exif/1.0/" xmlns:lptc4xmpCore="http://iptc.org/std/lptc4xmpCore/1.0/xmlns/"
xmlns:xapRights="http://ns.adobe.com/xap/1.0/rights/" photoshop:Source="CREATOR"
photoshop:Headline="HEADLINE" photoshop:Credit="CREDIT" photoshop:DateCreated="2001-01-01"
photoshop:History="" avm:Distance.Notes="DISTANCE.NOTES" avm:ReferenceURL="REFERENCEURL"
avm:Type="Observation" avm:Image.ProductQuality="Good" avm:ID="ID" avm:Spatial.CoordinateFrame="ICRS"
avm:Spatial.Equinox="SPATIAL.EQUINOX" avm:Spatial.CoordsystemProjection="TAN" avm:Spatial.Quality="Full"
avm:Spatial.Rotation="SPATIAL.ROTATION" avm:Publisher="PUBLISHER" avm:PublisherID="PUBLISHERID"
avm:ResourceID="RESOURCEID" avm:ResourceURL="RESOURCEURL" avm:MetadataVersion="1.1"
avm:MetadataDate="2010-01-01" <dc:creator> <rdf:Seq> <rdf:li>CONTACT.NAME</rdf:li> </rdf:Seq> </dc:creator>
<dc:title> <rdf:Alt> <rdf:li xml:lang="x-default">TITLE</rdf:li> </rdf:Alt> </dc:title> <dc:description> <rdf:Alt> <rdf:li
xml:lang="x-default">DESCRIPTION</rdf:li> </rdf:Alt> </dc:description> <dc:subject> <rdf:Bag>
<rdf:li>SUBJECT.NAME</rdf:li> </rdf:Bag> </dc:subject> <xapMM:DerivedFrom
stRef:instanceID="uuid:34B10B47D0DA11DCACA2B4F263B1292A"
stRef:documentID="uuid:17BC3B25D02311DC876195207E38F60E"/> <avm:Subject.Category> <rdf:Bag>
<rdf:li>SUBJECT.CATEGORY</rdf:li> </rdf:Bag> </avm:Subject.Category> <avm:Facility> <rdf:Seq>
<rdf:li>FACILITY</rdf:li> </rdf:Seq> </avm:Facility> <avm:Instrument> <rdf:Seq> <rdf:li>INSTRUMENT</rdf:li> </rdf:Seq>
</avm:Instrument> <avm:Spectral.ColorAssignment> <rdf:Seq> <rdf:li>SPECTRAL.COLORASSIGNMENT</rdf:li>
</rdf:Seq> </avm:Spectral.ColorAssignment> <avm:Spectral.Band> <rdf:Seq> <rdf:li>SPECTRAL.BAND</rdf:li>
</rdf:Seq> </avm:Spectral.Band> <avm:Spectral.Bandpass> <rdf:Seq> <rdf:li>SPECTRAL.BANDPASS</rdf:li>
</rdf:Seq> </avm:Spectral.Bandpass> <avm:Spectral.CentralWavelength> <rdf:Seq>
<rdf:li>SPECTRAL.CENTRALWAVELENGTH</rdf:li> </rdf:Seq> </avm:Spectral.CentralWavelength>
```

Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

```
<avm:Spectral.Notes> <rdf:Alt> <rdf:li xml:lang="x-default">SPECTRAL.NOTES</rdf:li> </rdf:Alt> </avm:Spectral.Notes>
<avm:Temporal.StartTime> <rdf:Seq> <rdf:li>TEMPORAL.STARTTIME</rdf:li> </rdf:Seq> </avm:Temporal.StartTime>
<avm:Temporal.IntegrationTime> <rdf:Seq> <rdf:li>TEMPORAL.INTEGRATIONTIME</rdf:li> </rdf:Seq>
</avm:Temporal.IntegrationTime> <avm:DatasetID> <rdf:Seq> <rdf:li>DATASETID</rdf:li> </rdf:Seq> </avm:DatasetID>
<avm:Spatial.ReferenceValue> <rdf:Seq> <rdf:li>SPATIAL.REFERENCEVALUE</rdf:li> </rdf:Seq>
</avm:Spatial.ReferenceValue> <avm:Spatial.ReferenceDimension> <rdf:Seq>
<rdf:li>SPATIAL.REFERENCEDIMENSION</rdf:li> </rdf:Seq> </avm:Spatial.ReferenceDimension>
<avm:Spatial.ReferencePixel> <rdf:Seq> <rdf:li>SPATIAL.REFERENCEPIXEL</rdf:li> </rdf:Seq>
</avm:Spatial.ReferencePixel> <avm:Spatial.Scale> <rdf:Seq> <rdf:li>SPATIAL.SCALE</rdf:li> </rdf:Seq>
</avm:Spatial.Scale> <avm:Spatial.Notes> <rdf:Alt> <rdf:li xml:lang="x-default">SPATIAL.NOTES</rdf:li> </rdf:Alt>
</avm:Spatial.Notes> <avm:Spatial.FITSHeder> <rdf:Alt> <rdf:li xml:lang="x-default">SPATIAL.FITSHEADER</rdf:li>
</rdf:Alt> </avm:Spatial.FITSHeder> <avm:Spatial.CDMatrix> <rdf:Seq> <rdf:li>SPATIAL.CDMATRIX</rdf:li> </rdf:Seq>
</avm:Spatial.CDMatrix> <avm:RelatedResources> <rdf:Bag> <rdf:li>RELATEDRESOURCES</rdf:li> </rdf:Bag>
</avm:RelatedResources> <iptc4xmpCore:CreatorContactInfo Iptc4xmpCore: CiEmailWork="CONTACT.EMAIL; EMAIL2;
EMAIL3" Iptc4xmpCore: CiTelWork="CONTACT.TELEPHONE; PHONE2; PHONE3"
Iptc4xmpCore: CiAdrExtadr="CONTACT.ADDRESS" Iptc4xmpCore: CiAdrCity="CONTACT.CITY"
Iptc4xmpCore: CiAdrRegion="CONTACT.STATEPROVINCE" Iptc4xmpCore: CiAdrPcode="CONTACT.POSTALCODE"
Iptc4xmpCore: CiAdrCtry="CONTACT.COUNTRY" Iptc4xmpCore: CiUrlWork="CREATORURL"/>
<xapRights:UsageTerms> <rdf:Alt> <rdf:li xml:lang="x-default">RIGHTS</rdf:li> </rdf:Alt> </xapRights:UsageTerms>
</rdf:Description> </rdf:RDF> </x:xmpmeta>
```

7.5 Local-Use Custom XMP Tags

The AVM schema was designed to capture the core metadata to describe an image resource, but it does not encompass every possible descriptor by any means. Individual users may wish to add additional tags to the AVM schema to cover local metadata needs.

For instance, if a Content Management System (CMS) is developed for a website based on AVM, it may be useful to expand the existing tags to cover any additional metadata needs for the specific website and unify the treatment of metadata. However, since AVM will likely expand in the future it is important to use a naming convention that will not possibly overlap with future tag descriptors, an especially important consideration when the tags are embedded using XMP.

The recommendation is that any additional local-use extensions to the AVM follow the form “X.tagname” to minimize confusion. This is similar to the convention established for the object taxonomy for introducing local-use extensions for the “Object.Type” tag (section 3.1.3).

Any code that parses AVM for general use should therefore ignore any tag beginning with “X.” For example:

```
<avm:X.GalleryName>Chandra's Greatest Hits</avm:MetadataVersion>
<avm:X.ObserverNames>
  <rdf:Bag>
    <rdf:li>E. Hubble</rdf:li>
    <rdf:li>L. Spitzer</rdf:li>
  </rdf:Bag>
```

8 Appendix E: AVM Full Properties Summary Table

AVM Tag Name	Format	XMP Tag	Inner Tags	IPTC Equiv.	Related UCD1+
Creator	string	<photoshop:Source>		Source	meta.curation
CreatorURL	URL	< ptc4xmpCore:CIUrlWork>		Website(s)	–
Contact.Name	string, list	<dc:creator>	<rdf:Seq><rdf:li>	Creator	–
Contact.Email	string, list	< ptc4xmpCore:CIEmailWork>		E-Mail(s)	meta.email
Contact.Telephone	string, list	< ptc4xmpCore:CITelWork>		Phone(s)	–
Contact.Address	string	< ptc4xmpCore:CIAdrExtadr>		Address	–
Contact.City	string	< ptc4xmpCore:CIAdrCity>		City	–
Contact.StateProvince	string	< ptc4xmpCore:CIAdrRegion>		State/Province	–
Contact.PostalCode	string	< ptc4xmpCore:CIAdrPcode>		Postal code	–
Contact.Country	string	< ptc4xmpCore:CIAdrCtry>		Country	–
Rights	string	<xapRights:UsageTerms>	<rdf:Alt><rdf:li xml:lang="x-default">	Rights Usage Terms	–
Title	string	<dc:title>	<rdf:Alt><rdf:li xml:lang="x-default">	Title	–
Headline	string	<photoshop:Headline>		Headline	meta.title
Description	string	<dc:description>	<rdf:Alt><rdf:li xml:lang="x-default">	Description	meta.note
Subject.Category	string-CV, list	<avm:Subject.Category>	<rdf:Bag><rdf:li>	–	–
Subject.Name	string, list	<dc:subject>	<rdf:Bag><rdf:li>	Keywords	meta.id
Distance	string, list(2)	<avm:Distance>	<rdf:Seq><rdf:li>	–	–
Distance.Notes	string	<avm:Distance.Notes>		–	–
ReferenceURL	URL	<avm:ReferenceURL>		–	meta.ref.url
Credit	string	<photoshop:Credit>		Provider	meta.curation
Date	date	<photoshop:DateCreated>		Date Created	time.release
ID	string	<avm:ID>		–	–
Type	string-CV	<avm:Type>		–	–
Image.ProductQuality	string-CV	<avm:Image.ProductQuality>		–	–
Facility	string, list(s)	<avm:Facility>	<rdf:Seq><rdf:li>	–	instr.tol
Instrument	string, list(s)	<avm:Instrument>	<rdf:Seq><rdf:li>	–	Instr
Spectral.ColorAssignment	string-CV, list(s)	<avm:Spectral.ColorAssignment>	<rdf:Seq><rdf:li>	–	–
Spectral.Band	string-CV, list(s)	<avm:Spectral.Band>	<rdf:Seq><rdf:li>	–	em.[band]
Spectral.Bandpass	string, list(s)	<avm:Spectral.Bandpass>	<rdf:Seq><rdf:li>	–	em.[band].[range]
Spectral.CentralWavelength	float, list(s)	<avm:Spectral.CentralWavelength>	<rdf:Seq><rdf:li>	–	em.wl.central
Spectral.Notes	string	<avm:Spectral.Notes>	<rdf:Alt><rdf:li xml:lang="x-default">	–	–
Temporal.StartTime	date, list(s)	<avm:Temporal.StartTime>	<rdf:Seq><rdf:li>	–	time.start
Temporal.IntegrationTime	float, list(s)	<avm:Temporal.IntegrationTime>	<rdf:Seq><rdf:li>	–	obs.exposure
DatasetID	string, list(s)	<avm:DatasetID>	<rdf:Seq><rdf:li>	–	meta.dataset

Astronomy Visualization Metadata (AVM) Standard - *Version 1.1*

AVM Tag Name	Format	XMP Tag	Inner Tags	IPTC Equiv.	Related UCD1+
Spatial.CoordinateFrame	string-CV	<avm:Spatial.CoordinateFrame>		–	pos.frame
Spatial.Equinox	string	<avm:Spatial.Equinox>		–	time.equinox
Spatial.ReferenceValue	float, list(2)	<avm:Spatial.ReferenceValue>	<rdf:Seq><rdf:li>	–	pos.wcs.crval
Spatial.ReferenceDimension	float, list(2)	<avm:Spatial.ReferenceDimension>	<rdf:Seq><rdf:li>	–	pos.wcs.naxis
Spatial.ReferencePixel	float, list(2)	<avm:Spatial.ReferencePixel>	<rdf:Seq><rdf:li>	–	pos.wcs.crpix
Spatial.Scale	float, list(2)	<avm:Spatial.Scale>	<rdf:Seq><rdf:li>	–	pos.wcs.scale
Spatial.Rotation	float	<avm:Spatial.Rotation>		–	–
Spatial.CoordsystemProjection	string-CV	<avm:Spatial.CoordsystemProjection>		–	pos.wcs.ctype
Spatial.Quality	string-CV	<avm:Spatial.Quality>		–	–
Spatial.Notes	string	<avm:Spatial.Notes>	<rdf:Alt><rdf:li xml:lang="x- default">	–	–
Spatial.FITSheader	string	<avm:Spatial.FITSheader>		–	–
Spatial.CDMatrix	float, list(4)			–	–
Publisher	string	<avm:Publisher>		–	meta.curation
PublisherID	string	<avm:PublisherID>		–	–
ResourceID	string	<avm:ResourceID>		–	–
ResourceURL	URL	<avm:ResourceURL>		–	–
RelatedResources	list	<avm:RelatedResources>	<rdf:Bag><rdf:li>	–	–
MetadataDate	date	<avm:MetadataDate>		–	–
MetadataVersion	string	<avm:MetadataVersion>		–	–
File.Type	string-CV	n/a		–	–
File.Dimension	float, list(2)	n/a		–	–
File.Size	float, list(2)	n/a		–	–
File.BitDepth	float	n/a		–	–