***I**nternational*

***V**irtual*

***O**bservatory*

***A**lliance*

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

Version 1.10 - DRAFT
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Working Group:
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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: Final revision prior to AAS feedback session

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Revision History

AVM Version 1.0: September 2006

AVM Version 1.1: DRAFT October 2007 – January 2008

Modifications from v1.0 to v1.1:

- Editor’s Notes added for more effective community feedback discussions
- More detailed information added for each tag definition
- Redesigned informational tables to show proper example metadata, tags, IPTC, and UCD1+ equivalencies/translations
- Full example XMP file added into Appendix
- Reformat of *Section 4: Metadata Definitions*
- Various text/wording modifications and new sections of text were added.
- Added more footnotes to software packages, existing standards, and organizations
- Reference to *AVM Users Guide for Dummies* added in 1.5 Implementation
- Addition of new Appendice, C: WCS Representation in the AVM. Consequently, Appendix C from Version 1.0 is now Appendix D and Appendix D from Version 1.0 is now Appendix E.

Modifications to Existing Tags:

- ‘Coverage’ removed from ‘**Spatial.**’ tags as it was deemed unnecessary
- **ResourceID** now reflects a content provider’s naming schema for their image files. Used now in conjunction with the new tag **ResourceURL**.

- *Section 2.2 Recommended Levels of Tagging* replaces “Levels of Requirement” to better describe why certain metadata fields are necessary and the effects if tags are left out of a submission.
- A new **Type** of image was added: Collage
- **CreatorURL** now references the IPTC tag *Iptc4xmpCore:CiUrlWork*.
- 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.
- **MetadataVersion** now resides in the Publisher tagset.

New Tags:

- The **Title** tag now holds the data formerly in **Headline** as **Headline** was redefined.
- **MetadataDate** under Publisher tagset
- **ResourceURL** under Publisher tagset
- **RelatedResources** under Publisher tagset

Retired Tags:

- **CDMatrix**

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)[1].

1.1 Intended Scope of AVM Metadata Schema

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

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

The primary focus of this document is on print-ready and screen ready astronomical imagery, which has been rendered from telescopic observations (also known as “pretty pictures”). Such images can combine data acquired at different wavebands and from different observatories. While the primary intent is to cover data-derived astronomical images, there are broader uses as well. Specifically, the most general subset of this schema is also appropriate for describing artwork and illustrations of astronomical subject matter. This 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 define the key elements needed in a practical database for identification of desired resources. For example, one might choose to search for images of the Crab Nebula that include both X-ray and visible light elements, or for any images within 2 degrees of a specified location on the sky that include at least some data from the Spitzer Space Telescope.

Future plans include “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 it remains easily associated with the image for all users. Once an image is separated from its

[1] For more info see the VAMP homepage at http://virtualastronomy.org

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) specification describes a widely-used method for embedding arbitrary metadata within images. XMP tags are stored within the image header of all common image formats (JPEG, TIF, PNG, GIF, PSD) and can be read by popular image processing and cataloguing 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. It 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 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 larger degree than possible today. One could imagine a small observatory or an amateur astronomer possessing only the resources to establish an online gallery, but allowing its contents to be searched by an external data-mining package. Or the image files could be uploaded to a curated site that itself might interface with the VO.

1.3 Referenced Standards

The schema described here has been developed within several existing standards. These include the Virtual Observatory (VO), the International Press Telecommunications Council (IPTC)[2], and the Adobe© Extensible Metadata Platform (XMP)[3].

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

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[2] IPTC Metadata for XMP: http://www.iptc.org/IPTC4XMP/
[3] Adobe XMP, Adding Intelligence to Media: http://www.adobe.com/products/xmp/
[4] Simple Image Access Specification: http://www.ivoa.net/Documents/latest/SIA.html

Translations between the AVM and Virtual Observatory (VO) vocabularies (like the Resource Metadata[5] or Unified Content Descriptors[6]) are possible. The equivalent UCD tags are listed in Table 3.2. Resource Metadata (RM) is used by VOs to describe an entire collection while the UCDs are used to describe components of an individual data set within a controlled vocabulary framework.

The methods for embedding metadata directly within the image files are described within the Adobe© XMP specification[7]. This provides an XML system for encoding the data, methods for directly editing the tags within Adobe© Photoshop[8], as well as a developer's Software Development Kit[9] for developing custom software applications to read the embedded tags.

The IPTC has utilized an extensive XMP metadata schema[10] for embedding descriptive information within photographs. The 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 World Coordinate System (WCS) tags that fully describe the image location, scale, and orientation on the sky. The advantages of a fully-tagged dataset are potentially enormous. They may be located in position-based queries like any full scientific dataset. In addition, it is possible for users to develop software to allow for automatic image registration and alignment; for instance for automatic inclusion in digital planetarium projections.

Please see Appendix C for detailed information, definitions and arguments on the WCS representation in the AVM.

Editor's Note: Decisions and further development of the WCS tagset are being discussed within a small group of collaborators and will be further discussed in the larger forum at the AAS 2008 winter meeting.

1.5 Implementation

Current tools for entry of AVM metadata tags area available as part of the ESA/ESO/NASA Photoshop FITS Liberator[11] Version 2.1, released in March

[5] Resource Metadata for the Virtual Observatory: http://www.ivoa.net/Documents/latest/RM.html
[6] 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
[7] Adobe XMP: http://www.adobe.com/products/xmp/overview.html
[8] Adobe Photoshop: http://www.adobe.com/products/photoshop/photoshop/
[9] Adobe XMP Developer Center: http://www.adobe.com/devnet/xmp/
[10] IPTC Metadata for XMP: http://www.iptc.org/IPTC4XMP/
[11] FITS Liberator: http://www.spacetelescope.org/projects/fits_liberator

2006. The 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 also can populate the AVM fields during the conversion between FITS data and 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: AVM Tagging Tool, CSV to XMP script and Subject.Category Generator. These tools sit on http://virtualastronomy.org.

Please find our *AVM Users Guide for Dummies* and current AVM XMP panels for Adobe 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 an 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 the Appendix for a sample XMP file.

2 AVM Metadata Tag Descriptions

2.1 Tag Formats

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

- String – a free-format text field
- String-CV – a string with predefined values taken from a "controlled vocabulary" (CV)
- Float – a floating-point number
- URL – universal resource locator, a standard web address

"Controlled vocabulary" items use predefined values to facilitate database searching by assuring all related search elements use standardized terminology. All controlled vocabulary lists for tags may be found in Appendix A.

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

- List – can have any number of elements
- List(n) – has exactly n elements
- List-ordered (LO) – a multi-element list where order is correlated between tags

Note that the "list-ordered" property applies specifically to a set of 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.

2.2 Recommended Levels of Tagging

To form a meaningful database for user searches, certain sets of AVM metadata tags are suggested. If an observational image of The Sombrero Galaxy is not tagged with WCS coordinates, then it will not be found and used by desktop planetarium software. In other instances, if an image does not contain the **Subject.name** or **Subject.category** tags, it will not be found by semantic applications that want to show their users related images. If **Title**, **Description**, **Subject.name** or **Subject.category** are not given, then keyword searches would fail to locate and deliver the image.

The suggested requirement levels for the minimum set of tags to render a resource valid for anticipated end-user purposes are:

- To allow an image to be located by a cone search on the sky (lacks scale and projection):
  - **Spatial.CoordinateFrame**
  - **Spatial.Equinox**
  - **Spatial.ReferenceValue**
  - **Spatial.Quality**
- To place an observational image on a sky grid:
  - **Spatial.CoordinateFrame**
  - **Spatial.Equinox**
  - **Spatial.ReferenceValue**
  - **Spatial.Quality**
  - **Spatial.ReferenceDimension**
  - **Spatial.ReferencePixel**
  - **Spatial.Scale**
  - **Spatial.Rotation**

    - **Spatial.CoordsystemProjection**
- Tags to consider for keyword/semantic searching (not all required):
    - **Headline**
    - **Subject.Category**
    - **Subject.Name**
    - **Description**
    - **Facility**
    - **Instrument**
- There is a minimum requirement level for successful submission to the VAMP Archive:
    - **MetadataVersion**
    - **Creator**
    - **Rights**
    - **Credit**
    - **ID**
    - **ResourceID**
- The following tags are automatically generated when an image is submitted to VAMP, as they are the standard file properties. These tags should not be user-editable:
    - **File.Type**
    - **File.Dimension**
    - **File.Size**
    - **File.BitDepth**

AVM Schema Summary Tables

The following two tables summarize the specifications and examples for the AVM standard. Detailed descriptions are in Section 3.

2.3 AVM Example Tags and Metadata

Tag Name	Format	Example Metadata
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
Content Metadata		
Headline	string	Spiral Galaxy NGC 1566 in Dorado.
Title	string	NGC 1566
Subject.Category	string, list, CV	C.5.1.1;C.5.3.2.2
Subject.Name	string, list	NGC 1566
Description	string	This beautiful spiral galaxy NGC 1566, located approximately 60 million light-years away in the constellation Dorado was captured by the Spitzer Infrared Nearby Galaxies Survey (SINGS) Legacy Project using the telescope's Infrared Array Camera.
ReferenceURL	URL	http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=sig05-013
Credit	string	NASA/JPL-Caltech
Date	string	2005-09-15
ID	string	sig05-013
Type	string, CV	Observation
Image.ProductQuality	string, CV	Good
Observation Metadata		
Facility	string, LO	Spitzer;Spitzer;Spitzer;Spitzer
Instrument	string, LO	IRAC;IRAC;IRAC;IRAC
Spectral.ColorAssignment	string, LO ,CV	Blue;Green;Red;Red

Spectral.Band	string, LO CV	Infrared;Infrared;Infrared;Infrared
Spectral.Bandpass	string, LO	Near-Infrared;Near-Infrared;Near-Infrared;Near-Infrared
Spectral.CentralWavelength	float, LO	3600;4500;5800;8000
Spectral.Notes	string	The SINGS image is a four-channel false-color composite, where blue indicates emission at 3.6 microns, green corresponds to 4.5 microns, and red to 5.8 and 8.0 microns. The contribution from starlight (measured at 3.6 microns) in this picture has been subtracted from the 5.8 and 8 micron images to enhance the visibility of the dust features.
Temporal.StartTime	float, LO	2002-12-21-0900; 2002-12-21-0900; 2002-12-21-0900; 2002-12-21-0900
Temporal.IntegrationTime	float, LO	10;10;10;10
DatasetID	URI, LO	a1;a2;a3;a4
Spatial.CoordinateFrame	string, CV	ICRS
Spatial.Equinox	string	2000.0
Spatial.ReferenceValue	float, list(2)	65.0696476555;54.9319798442
Spatial.ReferenceDimension	float, list(2)	974;974
Spatial.ReferencePixel	float, list(2)	616.293197632;346.155345917
Spatial.Scale	float, list (2)	-0.000208670950176;0.000208670950176
Spatial.Rotation	float	-124.205032386
Spatial.CoordsystemProjection	string, CV	TAN
Spatial.Quality	string, CV	Full
Spatial.Notes	string	FOV: 12.19 x 12.19 arcminutes; Ref coordinate: 4h20m16.72s -54d55m55.13s; derived from astrometry.net file sig05-013.fits
Publisher Metadata		
Publisher	string	Spitzer Space Telescope
PublisherID	string	1
ResourceID	list	sig05-013_sm.jpg
ResourceURL	URI	http://gallery.spitzer.caltech.edu/Imagegallery
RelatedResources	list	
MetadataVersion	string	1.1
MetadataDate	string	11/17/2007
File Metadata (implicit, not user entered)		
File.Type	string, CV	JPEG
File.Dimension	float, list(2)	974;974
File.Size	float	180
File.BitDepth	float	16

2.4 AVM Technical Table

AVM Standard Tag Name	Path/Data Source Photoshop (XMP)	XMP Tag	IPTC Equivalent	UCD1+ Equivalency
Creator Metadata				
Creator	photoshop:Source	<photoshop:Source>	Source	meta.curation
CreatorURL	avm	<Iptc4xmpCore:CiUrlWork >	CiUrlWork	----- none -----
Contact.Name	xap_ns_dc:creator	<dc:creator>	Creator	----- none -----
Contact.Email	CreatorContactInfo/Iptc4xmpCore:CiEmailWork	<Iptc4xmpCore:CiEmailWork>	CiEmailWork	meta.email
Contact.Telephone	CreatorContactInfo/Iptc4xmpCore:CiTelWork	<Iptc4xmpCore:CiTelWork>	CiTelWork	----- none -----
Contact.Address	CreatorContactInfo/Iptc4xmpCore:CiAdrExtadr	<Iptc4xmpCore:CiAdrExtadr>	CiAdrExtadr	----- none -----
Contact.City	CreatorContactInfo/Iptc4xmpCore:CiAdrCity	<Iptc4xmpCore:CiAdrCity>	CiAdrCity	----- none -----
Contact.StateProvince	CreatorContactInfo/Iptc4xmpCore:CiAdrRegion	<Iptc4xmpCore:CiAdrRegion>	CiAdrRegion	----- none -----
Contact.PostalCode	CreatorContactInfo/Iptc4xmpCore:CiAdrPcode	<Iptc4xmpCore:CiAdrPcode>	CiAdrPcode	----- none -----
Contact.Country	CreatorContactInfo/Iptc4xmpCore:CiAdrCtry	<Iptc4xmpCore:CiAdrCtry>	CiAdrCtry	----- none -----
Rights	xapRights:UsageTerms	<xapRights:UsageTerms>	RightsUsageTerms	----- none -----
Content Metadata				
Headline	photoshop:Headline	<photoshop:Headline >	Headline	meta.title
Title	dc:title	<dc:title>		----- none -----
Subject.Category	avm	<avm:Subject.Category>	----- none -----	----- n/a -----
Subject.Name	xap_ns_dc:subject	<dc:subject>	Keywords	meta.id
Description	xap_ns_dc:description	<dc:description>	Description	meta.note
ReferenceURL	avm	<avm:ReferenceURL>	----- none -----	meta.ref.url
Credit	photoshop:Credit	<photoshop:Credit>	Provider	meta.curation

Date	photoshop:DateCreated	<photoshop:DateCreated>	Date Created	time.release
ID	avm	<avm:ID>	----- none -----	----- none -----
Type	avm	<avm:Type>	----- none -----	----- none -----
Image.ProductQuality	avm	<avm:Image.ProductQuality>	----- none -----	----- none -----
Observation Metadata				
Facility	avm	<avm:Facility>	----- none -----	instr.tel
Instrument	avm	<avm:Instrument>	----- none -----	Instr
Spectral.ColorAssignment	avm	<avm:Spectral.ColorAssignment>	----- none -----	----- none -----
Spectral.Band	avm	<avm:Spectral.Band>	----- none -----	em.xx[12]
Spectral.Bandpass	avm	<avm:Spectral.Bandpass>	----- none -----	em.xx.yy[13]
Spectral.CentralWavelength	avm	<avm:Spectral.CentralWavelength>	----- none -----	em.wl.central
Spectral.Notes	avm	<avm:Spectral.Notes>	----- none -----	----- none -----
Temporal.StartTime	avm FITS: DATE-OBS	<avm:Temporal.StartTime>	----- none -----	time.start
Temporal.IntegrationTime	avm FITS: EXPTIME	<avm:Temporal.IntegrationTime>	----- none -----	time.interval or obs.exposure
DatasetID	avm	<avm:DatasetID>	----- none -----	meta.dataset
Spatial.CoordinateFrame	avm FITS: CFRAME	<avm:Spatial.CoordinateFrame>	----- none -----	pos.frame
Spatial.Equinox	avm FITS: Equinox	<avm:Spatial.Equinox>	----- none -----	time.equinox or time.epoch?
Spatial.ReferenceValue	avm FITS: CRVAL1, CRVAL2	<avm:Spatial.ReferenceValue>	----- none -----	pos.wcs.crval
Spatial.ReferenceDimension	avm FITS: NAXIS1, NAXIS2	<avm:Spatial.ReferenceDimension>	----- none -----	pos.wcs.naxis
Spatial.ReferencePixel	avm FITS: CRPIX1, CRPIX2	<avm:Spatial.ReferencePixel>	----- none -----	pos.wcs.crpix
Spatial.Scale	avm FITS: CDELT1, CDELT2	<avm:Spatial.Scale>	----- none -----	pos.wcs.scale
Spatial.Rotation	avm FITS: CROT1, CROT2	<avm:Spatial.Rotation>	----- none -----	----- none -----

[12] The UCD1+ em.*xx* refers to one of the following: em.radio, em.mm, em.IR, em.opt, em.UV, em.X-ray, em.gamma. See Appendix A 4.4 for the controlled vocabulary of the respective AVM tag.

[13] E.g. em.IR.3-4um. See *The UCD1+ controlled vocabulary Version 1.23*

Spatial.CoordsystemProjection	avm FITS: CTYPE1, CTYPE2	<avm:Spatial.CoordsystemProjection>	----- none -----	pos.wcs.ctype
Spatial.Quality	avm	<avm:Spatial.Quality>	----- none -----	----- none -----
Spatial.Notes	avm	<avm:Spatial.Notes>	----- none -----	----- none -----
Publisher Metadata				
Publisher	avm	<avm:Publisher>	----- none -----	meta.curation
PublisherID	avm	<avm:PublisherID>	----- none -----	-----
ResourceID	avm	<avm:ResourceID>	----- none -----	meta.ref.uri
ResourceURL	avm	<avm:ResourceURL>	----- none -----	----- none -----
RelatedResources	avm	<avm:RelatedResources>	----- none -----	----- none -----
MetadataVersion	avm	<avm:MetadataVersion>	----- none -----	----- none -----
MetadataDate	avm	<avm:<MetadataDate>	----- none -----	----- none -----
File Metadata (implicit, not user entered)				
File.Type	avm	<avm:File.Type>	----- none -----	----- none -----
File.Dimension	avm	<avm:File.Dimension>	----- none -----	----- none -----
File.Size	avm	<avm:File.Size>	----- none -----	----- none -----
File.BitDepth	avm	<avm:File.BitDepth>	----- none -----	----- none -----

3 Metadata 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**: additional information to aid in understanding
- **Requirement Level**: refers to section *2.2 Recommended Levels of Tagging*
- **IPTC equivalent**: shows how the tag is part of the existing IPTC metadata standard that Photoshop/XMP utilizes.
- **UCD1+ equivalent**: for those interested in translation layers between the AVM and the IVOA UCD1+ standard, this field shows where the tags are equivalent.
- **Format**: refers to section *2.1 Tag Formats*
- **XMP/Photoshop path**: illustrates the path that Photoshop uses to pull the metadata from the IPTC or XMP standard into AVM.
- **XMP tag**: shows how that tag will show in an XMP file exported from Photoshop.
- **Example metadata**: shows an example of appropriate metadata for a given tag

3.1 Creator Metadata

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

Tag name:	**Creator**
Definition:	Original creator of the resource at the organizational level.
Comments:	
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	Source
UCD1+ equivalent:	meta.curation
Format:	string
XMP/Photoshop Path:	photoshop:Source
XMP Tag:	<photoshop:Source>
Example metadata:	Spitzer Science Center

Tag name:	**CreatorURL**
Definition:	A simple URL pointing to the (top level) outreach webpage for the original creator (see 2. Creator).
Comments:	
Requirement Level:	none
IPTC equivalent:	CiUrlWork
UCD1+ equivalent:	none
Format:	URL
XMP/Photoshop Path:	none
XMP Tag:	< Iptc4xmpCore:CiUrlWork >
Example metadata:	http://www.spitzer.caltech.edu

Tag name:	**Contact.Name**
Definition:	Name(s) of the primary contact(s) for the resource.
Comments:	
Requirement Level:	none
IPTC equivalent:	Creator
UCD1+ equivalent:	none
Format:	string, list
XMP/Photoshop Path:	xap_ns_dc:creator
XMP Tag:	<dc:creator>
Example metadata:	R. Hurt

Tag name:	**Contact.Email**
Definition:	Email(s) of the primary contact(s) for the resource.
Comments:	In some cases, a contact may have a more reliable long-term email address than URL.
Requirement Level:	none
IPTC equivalent:	CiEmailWork
UCD1+ equivalent:	meta.email
Format:	string, list
XMP/Photoshop Path:	CreatorContactInfo/Iptc4xmpCore:CiEmailWork
XMP Tag:	<Iptc4xmpCore:CiEmailWork>
Example metadata:	example@ipac.caltech.edu

Tag name:	**Contact.Telephone**
Definition:	Telephone number(s) of the primary contact for the resource.
Comments:	
Requirement Level:	none
IPTC equivalent:	CiTelWork
UCD1+ equivalent:	none
Format:	string, list
XMP/Photoshop Path:	CreatorContactInfo/Iptc4xmpCore:CiTelWork
XMP Tag:	<Iptc4xmpCore:CiTelWork>
Example metadata:	555-555-5555

Tag name:	**Contact.Address**
Definition:	Street address of the primary contact for the resource.
Comments:	
Requirement Level:	none
IPTC equivalent:	CiAdrWork
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	CreatorContactInfo/Iptc4xmpCore:CiAdrExtadr
XMP Tag:	<Iptc4xmpCore:CiAdrExtadr>
Example metadata:	1200 E. California Blvd.

Tag name:	**Contact.City**
Definition:	City of the primary contact for the resource.
Comments:	
Requirement Level:	none
IPTC equivalent:	CiAdrCity
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	CreatorContactInfo/Iptc4xmpCore:CiAdrCity
XMP Tag:	<Iptc4xmpCore:CiAdrCity>
Example metadata:	Pasadena

Tag name:	**Contact.StateProvince**
Definition:	State or province of the primary contact for the resource.
Comments:	
Requirement Level:	none
IPTC equivalent:	CiAdrRegion
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	CreatorContactInfo/Iptc4xmpCore:CiAdrRegion
XMP Tag:	<Iptc4xmpCore:CiAdrRegion>
Example metadata:	California

Tag name:	**Contact.PostalCode**
Definition:	Zip or postal code of the primary contact for the resource.
Comments:	
Requirement Level:	none
IPTC equivalent:	CiAdrPcode
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	CreatorContactInfo/Iptc4xmpCore:CiAdrPcode
XMP Tag:	<Iptc4xmpCore:CiAdrPcode>
Example metadata:	91125

Tag name:	**Contact.Country**
Definition:	Country of the primary contact for the resource.
Comments:	
Requirement Level:	none
IPTC equivalent:	CiAdrCtry
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	CreatorContactInfo/Iptc4xmpCore:CiAdrCtry
XMP Tag:	<Iptc4xmpCore:CiAdrCtry>
Example metadata:	USA

Tag name:	**Rights**
Definition:	Copyright and related intellectual property rights description.
Comments:	Without copyright and rights management information, the VAMP Archive will not be able to properly and legally serve out images and metadata. At this time, we suggest all images/metadata be Public Domain and free use. Later versions of the AVM may accommodate various digital rights management scenarios and limitations.
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	RightsUsageTerms
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	xapRights:UsageTerms
XMP Tag:	<xapRights:UsageTerms>
Example metadata:	Public Domain

3.2 Content Metadata

This set of tags contains the contextual information for an image.

Tag name:	**Headline**
Definition:	Short description of the full caption.
Comments:	
Requirement Level:	For keyword/semantic searching
IPTC equivalent:	Headline
UCD1+ equivalent:	meta.title
Format:	string
XMP/Photoshop Path:	photoshop:Headline
XMP Tag:	<photoshop:Headline>
Example metadata:	Spiral Galaxy NGC 1566 in Doradus.

Tag name:	**Title**
Definition:	General descriptive title given to the image resource.
Comments:	
Requirement Level:	For keyword/semantic searching
IPTC equivalent:	
UCD1+ equivalent:	
Format:	string
XMP/Photoshop Path:	dc:title
XMP Tag:	<dc:title>
Example metadata:	NGC 1566

Tag name:	**Subject.Category**
Definition:	The type(s) of object or objects in the resource. If objects can be placed into multiple categories in the taxonomy they should all be listed. The controlled vocabulary is listed in Appendix A.
Comments:	
Requirement Level:	For keyword/semantic searching
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string, list, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Subject.Category>
Example metadata:	C.5.1.1; C.5.3.2.2

Tag name:	**Subject.Name**
Definition:	Proper names/catalog numbers for key objects in the image field.
Comments:	This should include any common or proper names (e.g. Mars; Whirlpool Galaxy; Orion Nebula) as well as common catalog identifiers. For deep-sky objects this should include common catalog identifiers (e.g. M 82; NGC 7337; IC 342). Such identifiers should be obtained from services like Simbad or NED (for extragalactic objects).
Requirement Level:	For keyword/semantic searching
IPTC equivalent:	Keywords
UCD1+ equivalent:	meta.id
Format:	string, list
XMP/Photoshop Path:	xap_ns_dc:subject
XMP Tag:	<dc:subject>
Example metadata:	NGC 1566

Tag name:	**Description**
Definition:	Full caption and related description text for the image resource.
Comments:	
Requirement Level:	For keyword/semantic searching
IPTC equivalent:	Description
UCD1+ equivalent:	meta.note
Format:	string
XMP/Photoshop Path:	xap_ns_dc:description
XMP Tag:	<dc:description>
Example metadata:	This beautiful spiral galaxy NGC 1566, located approximately 60 million light-years away in the constellation Dorado was captured by the Spitzer Infrared Nearby Galaxies Survey (SINGS) Legacy Project using the telescope's Infrared Array Camera.

Tag name:	**ReferenceURL**
Definition:	Webpage containing more information about this specific image.
Comments:	
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	meta.ref.url
Format:	URL
XMP/Photoshop Path:	none
XMP Tag:	<avm:ReferenceURL>
Example metadata:	http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=sig05-013

Tag name:	**Credit**
Definition:	The minimum information that the Publisher would like to see mentioned when the resource is used.
Comments:	It is mandatory for users of the resource to mention the **Credit** in the end-product. See also **Rights**.
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	Provider
UCD1+ equivalent:	meta.curation
Format:	string
XMP/Photoshop Path:	photoshop:Credit
XMP Tag:	<photoshop:Credit>
Example metadata:	NASA/JPL-Caltech

Tag name:	**Date**
Definition:	Date that the resource was created or made available. (YYYY-MM-DD).
Comments:	Also known in daily use as release date (note that this is distinct from the observation date, **Temporal.StartTime**).
Requirement Level:	none
IPTC equivalent:	DateCreated
UCD1+ equivalent:	time.release
Format:	string
XMP/Photoshop Path:	photoshop:DateCreated
XMP Tag:	<photoshop:DateCreated>
Example metadata:	2005-09-15

Tag name:	**ID**
Definition:	This is an identifier for the resource that is unique to the creator.
Comments:	This tag will be better defined once the VAMP Archive & Service is built and more technical specifics are known.
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	none
XMP Tag:	<avm:ID>
Example metadata:	sig05-013

Tag name:	**Type**
Definition:	The type of resource. The controlled vocabulary is listed in Appendix A.
Comments:	
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Type>
Example metadata:	Observation

Tag name:	**Image.ProductQuality**
Definition:	Qualitative image quality assessment. **Image.ProductQuality** is chosen from a pre-defined list. The controlled vocabulary is listed in Appendix A.
Comments:	
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Image.ProductQuality>
Example metadata:	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), the geometric projection on the sky, and the wavelength/color assignments used for composite images.

Much of this data can be derived from information in the FITS headers of the source data. However, if multiple datasets are combined for a color image, each of the list-ordered tags must have the information for each color channel assigned in the correct order. For instance, for a simple 3-channel RGB image, the **Spectral.ColorAssignment** tag may be set to “Red; Green; Blue” and subsequent list-ordered tags should identify the contents of the red, green, and blue channels respectively.

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

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

Please see Appendix C for detailed information, definitions and arguments on the WCS representation in the AVM.

Tag name:	**Facility**
Definition:	Telescopes or observatories used for the observations.
Comments:	For this keyword, the list should reference facilities in order of the elements in the composite image.
Requirement Level:	For keyword/semantic searching
IPTC equivalent:	none
UCD1+ equivalent:	instr.tel
Format:	string, list-ordered
XMP/Photoshop Path:	none
XMP Tag:	<avm:Facility>
Example metadata:	Spitzer;Spitzer;Spitzer;Spitzer

Tag name:	**Instrument**
Definition:	Instrument used to collect the data. One Instrument per exposure.
Comments:	
Requirement Level:	For keyword/semantic searching
IPTC equivalent:	none
UCD1+ equivalent:	instr
Format:	string, list-ordered
XMP/Photoshop Path:	none
XMP Tag:	<avm:Instrument>
Example metadata:	IRAC;IRAC;IRAC;IRAC

Tag name:	**Spectral.ColorAssignment**
Definition:	The output color that is assigned to an exposure. One **Spectral.ColorAssignment** per exposure. The controlled vocabulary is listed in Appendix A.
Comments:	
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string, list-ordered, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spectral.ColorAssignment>
Example metadata:	Blue;Green;Red;Red

Tag name:	**Spectral.Band**
Definition:	Waveband of the component exposure from a pre-defined list defining the general part of the spectrum covered. One **Spectral.Band** per exposure.
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.
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	em.*xx* The UCD em.xx refers to one of the following: em.radio, em.mm, em.IR, em.opt, em.UV, em.X-ray, em.gamma.
Format:	string, list-ordered, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spectral.Band>
Example metadata:	Infrared;Infrared;Infrared;Infrared

Tag name:	**Spectral.Bandpass**
Definition:	Bandpass of the individual exposure. One **Spectral.Bandpass** 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).
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	em.*xx.yy* E.g. em.IR.3-4um. See The UCD1+ controlled vocabulary Version 1.23
Format:	string, list-ordered
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spectral.Bandpass>
Example metadata:	Near-infrared; Near-infrared; Near-infrared; Near-infrared

Tag name:	**Spectral.CentralWavelength**
Definition:	Central wavelength of the filter used for the individual exposure measured in nanometers. One **Spectral.CentralWavelength** per exposure.
Comments:	
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	em.wl.central
Format:	float, list-ordered
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spectral.CentralWavelength>
Example metadata:	3600;4500;5800;8000

Tag name:	**Spectral.Notes**
Definition:	Free-text field to allow for more detailed discussions of bandpasses and color mappings.
Comments:	
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spectral.Notes>
Example metadata:	The SINGS image is a four-channel false-color composite, where blue indicates emission at 3.6 microns, green corresponds to 4.5 microns, and red to 5.8 and 8.0 microns. The contribution from starlight (measured at 3.6 microns) in this picture has been subtracted from the 5.8 and 8 micron images to enhance the visibility of the dust features.

Tag name:	**Temporal.StartTime**
Definition:	Start time of the exposure in ISO 8601 format YYYY-MM-DD-HHMM [UT]. One **Temporal.StartTime** per exposure.
Comments:	This field can be populated from the FITS keyword DATE-OBS.
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	time.start
Format:	string, list-ordered
XMP/Photoshop Path:	none
XMP Tag:	<avm:Temporal.StartTime>
Example metadata:	2002-12-21-0900; 2002-12-21-0900; 2002-12-21-0900; 2002-12-21-0900

Tag name:	**Temporal.IntegrationTime**
Definition:	The exposure time in seconds. One **Temporal.IntegrationTime** per exposure.
Comments:	This is usually a more interesting quantity for general purposes than specific stop time, and more meaningful if the start time is only known approximately. This field can be populated from the FITS keyword EXPTIME.
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	time.interval or obs.exposure
Format:	float, list-ordered
XMP/Photoshop Path:	none
XMP Tag:	<avm:Temporal.IntegrationTime>
Example metadata:	10;10;10;10

Tag name:	**DatasetID**
Definition:	VO-compliant reference to the dataset (the exposure) used to construct the final image (if available). The format is [ivo://AuthorityID/ResourceKey]. One **DatasetID** per exposure.
Comments:	
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	time.start
Format:	URI, list-ordered
XMP/Photoshop Path:	none
XMP Tag:	<avm:DatasetID>
Example metadata:	a1;a2;a3;a4

Tag name:	**Spatial.CoordinateFrame**
Definition:	Coordinate system reference frame. **Spatial.CoordinateFrame** should be chosen from a pre-defined list.
Comments:	This field would be populated from the FITS keyword: CFRAME. Options include FK5, GAL etc. Consult Appendix A for specific options for this tag.
Requirement Level:	Required for cone search
IPTC equivalent:	none
UCD1+ equivalent:	pos.frame
Format:	string, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.CoordinateFrame>
Example metadata:	ICRS

Tag name:	**Spatial.Equinox**
Definition:	Equinox for **Spatial.CoordinateFrame**
Comments:	This field would be populated from the FITS keyword: Equinox. It usually defaults to J2000, except that the default for FK4 is B1950.
Requirement Level:	Required for cone search
IPTC equivalent:	none
UCD1+ equivalent:	time.equinox or time.epoch
Format:	string
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.Equinox>
Example metadata:	2000.0

Tag name:	**Spatial.ReferenceValue**
Definition:	Reference coordinates (RA and Dec) for the image (2 element list in decimal degrees).
Comments:	This and subsequent **Coverage.Spatial** tags deviate from existing VO standards for sky coordinates to more closely follow standards for FITS Keywords. This field would be populated from the FITS keywords: CRVAL1, 2.
Requirement Level:	Required for cone search
IPTC equivalent:	none
UCD1+ equivalent:	pos.wcs.crval
Format:	float, list(2)
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.ReferenceValue>
Example metadata:	65.0696476555; 54.9319798442

Tag name:	**Spatial.ReferenceDimension**
Definition:	Size of the image in pixels (2 element list).
Comments:	FITS Keywords: NAXIS1,2 (also equivalent to image dimensions).
Requirement Level:	Required for placement on sky grid
IPTC equivalent:	none
UCD1+ equivalent:	pos.wcs.naxis
Format:	float, list(2)
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.ReferenceDimension>
Example metadata:	974;974

Tag name:	**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 centre pixel in the image.
Requirement Level:	Required for placement on sky grid
IPTC equivalent:	none
UCD1+ equivalent:	pos.wcs.crpix
Format:	float, list(2)
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.ReferencePixel>
Example metadata:	616.293197632; 346.155345917

Tag name:	**Spatial.Scale**
Definition:	Spatial scale of the image in number of degrees/pixel (2 element list).
Comments:	FITS Keywords: CDELT1, CDELT2 (or derived from CD matrix). Is required for Simple Image Access operation (as per SIA Specification v. 1.0).
Requirement Level:	Required for placement on sky grid
IPTC equivalent:	none
UCD1+ equivalent:	pos.wcs.scale
Format:	float, list(2)
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.Scale>
Example metadata:	-0.000208670950176; 0.000208670950176

Tag name:	**Spatial.Rotation**
Definition:	Position angle of the Y axis in degrees measured east from north.
Comments:	FITS Keywords: CROT1,2 (the FITS standard allows for two values, but typically only one is used). Sky rotation is measured east from north which, for astronomical images, is counter-clockwise (east and west are reversed in a sky projection compared to a map projection). Is required for Simple Image Access operation (as per SIA Specification v. 1.0).
Requirement Level:	Required for placement on sky grid
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	float
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.Rotation>
Example metadata:	-124.205032386

Tag name:	**Spatial.CoordsystemProjection**
Definition:	A combination of the coordinate system and the projection of the image.
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. Consult Appendix A for specific options for this tag.
Requirement Level:	Required for placement on sky grid
IPTC equivalent:	none
UCD1+ equivalent:	pos.wcs.ctype
Format:	string, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.CoordinateSystemProjection>
Example metadata:	TAN

Tag name:	**Spatial.Quality**
Definition:	This qualitatively describes the reliability of the spatial coordinate information in this metadata. **Spatial.Quality** should be chosen from a pre-defined list.
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 (though may exclude CD matrix) • **Position** – **Spatial.ReferenceValue** describes a coordinate contained somewhere within the image; other WCS info is approximate or unreliable
Requirement Level:	Required for placement on sky grid
IPTC equivalent:	none
UCD1+ equivalent:	pos.wcs.cdmatrix
Format:	string, controlled vocabulary
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.Quality>
Example metadata:	Full

Tag name:	**Spatial.Notes**
Definition:	Free-text description to expand further on coordinates/geometry of image.
Comments:	This field can be used to include human-friendly descriptions of the image geometry (e.g. “RA=2h23m15.2s, Dec=-25d15m22s, field of view = 22 x 15 arcmin, north is 37 degrees clockwise from up”).
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	none
XMP Tag:	<avm:Spatial.Notes>
Example metadata:	FOV: 12.19 x 12.19 arcminutes; Ref coordinate: 4h20m16.72s -54d55m55.13s; derived from astrometry.net file sig05-013.fits; These coordinates had the y-reference pixel correction as well as the CD Matrix correction.

3.4 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** which 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.

Tag name:	**Publisher**
Definition:	Publisher of the resource
Comments:	Examples of a Publisher include a person or an organization.
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	meta.curation
Format:	string
XMP/Photoshop Path:	none
XMP Tag:	<avm:Publisher>
Example metadata:	Spitzer Space Telescope

Tag name:	**PublisherID**
Definition:	ID of publisher registered as VAMP providers.
Comments:	For instance a simple sign-up sheet on a central server. **PublisherID** is required if the data should be part of the VAMP.
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	meta.curation
Format:	URL
XMP/Photoshop Path:	none
XMP Tag:	<avm:PublisherID>
Example metadata:	1

Tag name:	**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:	This tag will be better defined once the VAMP Archive & Service is built and more technical specifics are known.
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	none
XMP Tag:	<avm:ResourceID>
Example metadata:	sig05-013_sm.jpg

Tag name:	**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:	This tag will be better defined once the VAMP Archive & Service is built and more technical specifics are known.
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	URL/URI
XMP/Photoshop Path:	none
XMP Tag:	<avm:ResourceURL>
Example metadata:	http://gallery.spitzer.caltech.edu/Imagegallery/

Tag name:	**RelatedResources**
Definition:	The format is a list of PublisherID/ID values that will reference specific resources registered in VAMP (though not specific “instances”).
Comments:	This tag will be better defined once the VAMP Archive & Service is built and more technical specifics are known.
Requirement Level:	none
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string
XMP/Photoshop Path:	none
XMP Tag:	<avm:RelatedResources>
Example metadata:	

Tag name:	**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.) changing this date flags the VAMP Archive to reload the resources.
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	Date
XMP/Photoshop Path:	none
XMP Tag:	<avm:MetadataDate>
Example metadata:	11/17/2007

Tag name:	**MetadataVersion**
Definition:	This is the version of the applied Metadata definition.
Comments:	
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	String
XMP/Photoshop Path:	none
XMP Tag:	<avm:MetadataVersion>
Example metadata:	1.1

3.5 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.

Tag name:	**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
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	string, CV
XMP/Photoshop Path:	none
XMP Tag:	<avm:File.Type >
Example metadata:	JPEG

Tag name:	**File.Dimension**
Definition:	Size in pixels (x, y) of the image resource.
Comments:	
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	float, list (2)
XMP/Photoshop Path:	none
XMP Tag:	<avm:File.Dimension >
Example metadata:	974;974

Tag name:	**File.Size**
Definition:	Size of the image resource, measured in kilobytes.
Comments:	
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	float
XMP/Photoshop Path:	none
XMP Tag:	<avm:File.Size>
Example metadata:	180

Tag name:	**File.BitDepth**
Definition:	Color bit-depth of the file, measured in total bits per pixel.
Comments:	
Requirement Level:	Required for submission to VAMP Archive
IPTC equivalent:	none
UCD1+ equivalent:	none
Format:	float
XMP/Photoshop Path:	none
XMP Tag:	<avm:File.BitDepth
Example metadata:	16

Appendix A: Controlled Vocabularies

Many of the metadata elements are strings which 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.

3.6 Subject.Category: Astronomical Object Taxonomy

Editor's Note: We are currently working with a small group of collaborators on redefining the Subject.Category tag and taxonomy. We plan on hosting a focus session to specifically look at this tag and what the needs are of the community for this tag/taxonomy to define/include.

Currently, the purpose of this tag is to characterize the subject matter or "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.

3.6.1 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

3.6.2 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
Typical taxonomy types: 3–5

D. Early Universe: era of galaxy formation and before
Typical taxonomy types: 5–6

E. Unspecified: for generic instance of subject
Typical taxonomy types: any

3.6.3 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
3.2.2. Carbon

3.2.3. Brown Dwarf
3.2.4. Wolf-Rayet
3.2.5. Blue Straggler
3.2.6. Exotic
3.3. [Spectral Type]
3.3.1. O
3.3.2. B
3.3.3. A
3.3.4. F
3.3.5. G
3.3.6. K
3.3.7. M
3.3.8. L
3.3.9. T
3.4. [Population]
3.4.1. I
3.4.2. II
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
- 5.5. [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
     - 7.1.6. Night glow
   - 7.2. Eclipse
     - 7.2.1. Solar
       - 7.2.1.1. Total
       - 7.2.1.2. Partial
       - 7.2.1.3. Annular
     - 7.2.2. Lunar
       - 7.2.2.1. Total
       - 7.2.2.2. Partial
       - 7.2.2.3. Penumbral
     - 7.2.3. Occultation
     - 7.2.4. Transit
   - 7.3. Light Phenomenon
     - 7.3.1. Sunrise-Sunset
       - 7.3.1.1. Green flash
       - 7.3.1.2. Refractive Distortion
       - 7.3.1.3. Sun Pillar
     - 7.3.2. Cloud
       - 7.3.2.1. Iridescent
       - 7.3.2.2. Noctilucent
       - 7.3.2.3. Nacreous
       - 7.3.2.4. Corona
       - 7.3.2.5. Glory
     - 7.3.3. Rainbow
       - 7.3.3.1. Moonbow
       - 7.3.3.2. Fogbow
     - 7.3.4. Halo
       - 7.3.4.1. Circle
       - 7.3.4.2. Parhelia
       - 7.3.4.3. Arc
     - 7.3.5. Ray-Shadow
       - 7.3.5.1. Crepuscular ray
       - 7.3.5.2. Anti-crepuscular ray
       - 7.3.5.3. Earth shadow
     - 7.3.6. Lightning
     - 7.3.7. Aurora
8. Technology
   - 8.1. Observatory
     - 8.1.1. Facility
     - 8.1.2. Telescope
     - 8.1.3. Instrument
   - 8.2. Spacecraft
     - 8.2.1. Orbiter
     - 8.2.2. Probe
     - 8.2.3. Lander
     - 8.2.4. Manned

3.7 Type

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

The AVM is primarily for education, public outreach, and press release images derived from astronomical datasets. However, artist conceptions, illustrations, image collages, and diagrams can also make use of the standard. The Creator, Content, Publisher, and File Metadata sections of the AVM should be used. The circumstances will dictate if the Observation metadata is applicable, though mostly it should not be used. For instance, a collage from Chandra may have a central focus of a Chandra Crab Nebula image. On the side for comparison are shown small tiles of a visible light image and a radio image. Even though the original Chandra image is an astronomical observation, this image should be tagged as a collage image type. The AVM Description tag should contain details about the collage elements and the original sources for those multi-wavelength tiles. This collage should not have WCS information included. Following best practices for press release images, Chandra should also submit a non-montage image of the Crab Nebula with Observation and WCS metadata. Any image that has multiple elements and/or image types (artwork, observation, photographic, planetary, simulation) should be listed as a collage.

The acceptable values for this tag are:

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

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. Only "Observation" types can be tagged with astronomical WCS coordinates. This image type (when accompanied by WCS coordinates) could in principle be directly added as resources served to VO queries by a VO data service provider.

"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 WCS coordinates.

"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.

"Photographic" and "Artwork" are both standard VO types from the document "Resource Metadata for the Virtual Observatory Version 1.1". "Observation" and "Planetary" are extensions to identify imagery that are derived from observational data (but are not calibrated data themselves).

3.8 ImageProductQuality

Limited terms to describe the subjective quality of the image.

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

3.9 Spectral.ColorAssignment

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

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

3.10 Spectral.Band: General Wavelength Regime

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

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

3.11 Spatial.CoordinateFrame

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

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

3.12 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)

3.13 Spatial.Quality: Coordinate Reliability

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

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

3.14 File.Type: Format of Image

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

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

4 Appendix B: Abbreviations

AVM Astronomical Outreach Imagery

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

5 Appendix C: WCS Representation in the 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 the same as for handling map projections on Earth. Since spheres are round and rectangles are flat one must of necessity distort one set of coordinates when projecting to the other geometry.

The WCS representation for astronomical FITS data is well established but due to differences between an arbitrary data representation format (FITS) and pictures in common image formats (JPEG, TIF, PNG, etc.), the specific interpretation of WCS for AVM must be specified. This appendix outlines the standard for interpreting WCS coordinates in WCS and explains the similarities and differences to WCS in FITS datasets.

5.1 WCS Basics and Defining Terms

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.

5.1.1 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, but in astronomy only a small handful are typically employed.

One of the most common for rendering small areas of sky is the “Tangent” 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 “Cartesian” projection is one for which the x, y image coordinates correspond proportionally to degree measurements in the sky. This is commonly used to represent all-sky images, though with increasing distortion towards the pole; the single point of the pole represents the entire top (or bottom) row of such an image. Distortion is minimal around the equator.

The related AVM tag is Spatial.CoordsystemProjection.

5.1.2 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).

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

5.1.3 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.

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

5.1.4 Scale and Orientation

The scale of the pixels (e.g. number of degrees per pixel) defines the overall coverage of the image. Also, it is possible that the image columns are not aligned with the "north" coordinate direction of the sky, so this rotation value must be specified as well.

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

5.1.5 Distortion Corrections

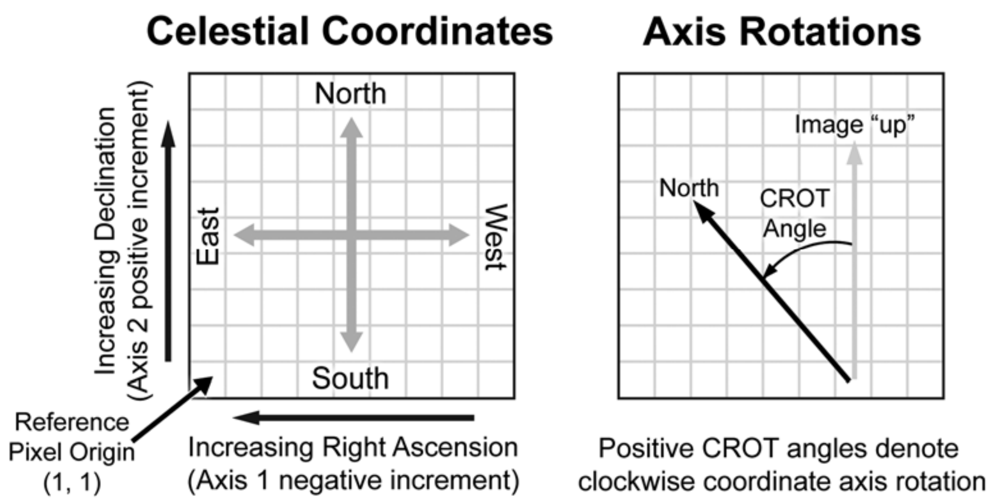
Often an image is not in fact a perfect representation of the specified projection. For instance, distortions in the optics can lead to complex distortion patterns in the final image. While distortion can be present at virtually any image scale due to optics and processing issues, they are particularly 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 related AVM Tags are Spatial.CDMatrix and Spatial.Distortion.

5.2 The WCS Representation in AVM

WCS projections in AVM are described relative to a regular Cartesian grid referenced to the image as it is normally displayed. The origin is conventionally taken to be at the lower left pixel of the displayed image. The figure below illustrates this 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") or counterclockwise. 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). This follows FITS conventions for pixel identification but is different than many programming conventions in which the first index element start at (0, 0). Thus if an image is 250 by 300 pixels in dimension, the upper left pixel would be (1, 300) and the upper right would be (250, 300).

5.3 Scale, Rotation, and CDMatrix Usage in AVM

Public-friendly images have almost certainly been rendered in such a way that the coordinate axes are orthogonal, or at right angles to each other. As such, specifying only a pixel scale and axis rotation are sufficient for describing the projection of such an image. The only oddity (as noted above) is that the increments along the x axis are typically negative to capture the decreasing increment in right ascension as one scans left to right.

Modern WCS implementations have deprecated the 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 orientations of each axis (allowing for skewed coordinate systems. In cases where there is no skew, there are straightforward equations to convert between CD matrix elements and the traditional scale and rotation values. This four-element matrix is contained in the AVM tag Spatial.CDMatrix.

5.3.1 When to Use Spatial.Scale & Spatial.Rotation

If an image clearly has orthogonal axes, and only the pixel scale and axis rotation values are easily recovered through convenient tools, then scale and rotation are sufficient and should be used. This has the added convenience of giving easily interpreted values, which may help educators working with the image and associated metadata outside of any AVM-savvy software packages.

5.3.2 When to Use Spatial.CDMatrix

If a coordinate solution has been derived for an image that has returned a CDMatrix then this should be used. It is possible that slight distortions in an image that *should* have orthogonal axes may result in a better alignment if a slight skew is included.

It is also critical to include the CDMatrix information if more detailed polynomial distortion corrections have been derived for the image in tandem with its CDMatrix solution. However, note that not all image display software will necessarily make use of skew and other distortion corrections even if present.

5.3.3 Which Takes Priority, Scale/Rotation or CDMatrix?

If both the Scale/Rotation and CDMatrix tags are present in a given image, then developers should give priority the CDMatrix solution. If the application reading this information can only utilize basic Scale/Rotation information, then this information can easily extracted from the CD matrix from the following equations. Likewise the reverse transform into a CDMatrix is easily implemented as well.

In general, code designed to read WCS info should be designed to make of whichever form of scaling information is supplied. This introduces a redundance for programmers but gives AVM implementers more options.

5.3.4 Converting between Scale/Rotation and CDMatrix

The spatial AVM descriptors are either single-valued or arrays of numbers. The corresponding FITS keywords for these values and elements are defined below (these keywords will be used as terms in subsequent equations):

Spatial.Scale = CDELT1; CDELT2 [degrees/pixel]

Spatial.Rotation = CROTA2 [degrees]

Spatial.CDMatrix = CD1_1; CD1_2; CD2_1; CD2_2 (CD matrix elements)

Note that CROTA2 is specifically the rotation of axis 2 (conventionally Declination or galactic longitude) with respect to the image grid. It is also possible, if unconventional, to independently describe to rotation of axis 1 using a CROTA1 term. For this term as well a positive rotation indicates an East of North sense away from the default array orientation. If the two axes are orthogonal then:

CROTA1 = CROTA2 = CROT

However, if CROTA1 ≠ CROTA2 then the coordinate grid is skewed.

Deriving CDMatrix from Scale/Rotation

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

$$\begin{pmatrix} CD1\_1 & CD1\_2 \\ CD2\_1 & CD2\_2 \end{pmatrix} = \begin{pmatrix} CDELT1 \cdot \cos(CROTA1) & -CDELT2 \cdot \sin(CROTA1) \\ CDELT1 \cdot \sin(CROTA2) & CDELT2 \cdot \cos(CROTA2) \end{pmatrix}$$

In the common convention where the rotations are identical and the scale elements are equal in magnitude but opposite in sign (defining CDELT to be positive):

$$CDELT1 = -CDELT$$
$$CDELT2 = CDELT$$
$$CROTA1 = CROTA2 = CROT$$

Then this transformation simplifies to:

$$\begin{pmatrix} CD1\_1 & CD1\_2 \\ CD2\_1 & CD2\_2 \end{pmatrix} = CDELT \cdot \begin{pmatrix} -\cos(CROT) & -\sin(CROT) \\ -\sin(CROT) & \cos(CROT) \end{pmatrix}$$

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 CD matrix elements:

$$CROTA1 = \arctan 2(-CD1\_2, \quad CD2\_2)$$
$$CROTA2 = \arctan 2(CD1\_1, \quad CD2\_1)$$
$$CROT = (CROTA1 + CROTA2)/2$$

The final average CROT value is a best average only for unskewed images.

A robust way of calculating the rotation which can handle unusual representations relies on the sign of the determinant of the CD matrix:

$$DET = CD1\_1 \cdot CD2\_2 - CD1\_2 \cdot CD2\_1$$
$$CROTA2 = \arctan 2(-\mathrm{sgn}(DET) \cdot CD1\_2, \quad CD2\_2)$$

The scale values follow from:

$$CDELT1 = \begin{cases} CD1\_1/\cos(CROTA1) & (CROTA1 \neq \pm 90°) \\ CD2\_1/\sin(CROTA2) & (CROTA2 > 0°) \end{cases}$$

$$CDELT2 = \begin{cases} -CD1\_2/\sin(CROTA1) & (CROTA1 > 0°) \\ CD2\_2/\cos(CROTA2) & (CROTA2 \neq \pm 90°) \end{cases}$$

5.4 Polynomial Distortion Corrections in AVM

A simple standard for encoding distortion terms is commonly used in FITS headers allowing for polynomial corrections of arbitrary order. The implementation of this information in the AVM Spatial.Distortion tag is to enter all the elements into a serial (keyword; value) ordered list. For instance, an example FITS header including distortion terms is:

```
A_ORDER =              2 / polynomial order, axis 1, detector to sky
A_0_2   =     -3.657E-08 / distortion coefficient
```

```
A_1_1   =    3.542E-05 / distortion coefficient
A_2_0   =    2.381E-05 / distortion coefficient
A_DMAX  =        0.985 / [pixel] maximum correction
B_ORDER =            2 / polynomial order, axis 2, detector to sky
B_0_2   =    4.282E-05 / distortion coefficient
B_1_1   =    2.379E-05 / distortion coefficient
B_2_0   =    6.547E-06 / distortion coefficient
B_DMAX  =        1.217 / [pixel] maximum correction
AP_ORDER=            2 / polynomial order, axis 1, sky to detector
AP_0_1  =    1.881E-05 / distortion coefficient
AP_0_2  =    3.615E-08 / distortion coefficient
AP_1_0  =    2.921E-05 / distortion coefficient
AP_1_1  =   -3.542E-05 / distortion coefficient
AP_2_0  =   -2.381E-05 / distortion coefficient
BP_ORDER=            2 / polynomial order, axis 2, sky to detector
BP_0_1  =    4.894E-05 / distortion coefficient
BP_0_2  =   -4.282E-05 / distortion coefficient
BP_1_0  =     2.65E-05 / distortion coefficient
BP_1_1  =   -2.379E-05 / distortion coefficient
BP_2_0  =   -6.548E-06 / distortion coefficient
```

The corresponding entries in the Spatial.Distortion tag would read:

A_ORDER; 2; A_0_2; -3.657E-8; A_1_1; 3.542E-05; A_2_0; …

Any software using these terms should be able to extract all of the expected terms following any arbitrary ordering of the labeling keywords. The keyword should always precede the value.

5.5 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 rederived 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.

RATIO = (current dimension)/(ReferenceDimension)

Current ReferencePixel = Spatial.ReferencePixel * RATIO

Current Scale = Spatial.Scale/RATIO

Current CDMatrix = Spatial.CDMatrix/RATIO

Note that the x and y scales may not be exactly equal due to roundoff 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).

5.6 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. This means following the "East is left of North" convention where the x scale is negative and the y scale is positive.
- Supply both Scale/Rotation and CDMatrix when possible. Tools that supply both give the best of both worlds and maximum flexibility.
- 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. There is a Spatial.Quality tag for indicating the level of reliability.

5.7 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 your image arrays starting with pixel (1,1) at the lower left corner, running (Xmax, Ymax) at the upper right.
- Look for images that have been proportionally rescaled from the stated Spatial.ReferenceDimension values and scale the WCS appropriately

5.8 Comparing AVM and FITS WCS Representations

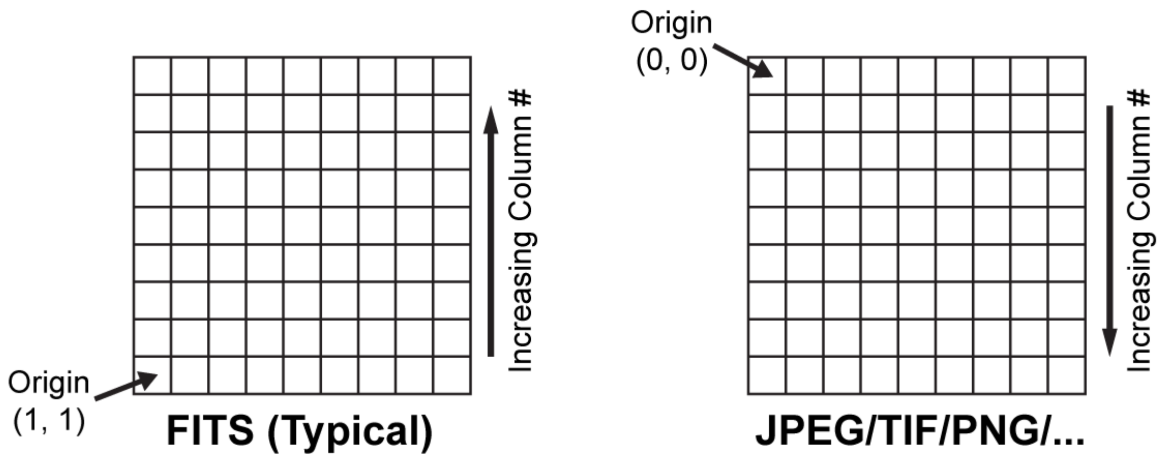
There are subtle but important differences between the FITS and AVM standards for WCS. These are rooted in the fundamental differences between these two formats and are worth expanding for clarity. This is particularly important since an imperfect understanding can result in images that are flipped and do not line up as expected.

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.

When a FITS file is used to represent a single image, it is generally defined as a data format with two axes, which will correspond to the two angular axes in the specified coordinate system. While conventionally these will often follow certain patterns such conventions are in no way a requirement. Axis order, rotations, and scalings can be represented in a variety of ways that all validly describe the data coordinates.

As a result there is no standard for how to display the array elements of a FITS file without interpreting the WCS projections. This is very different from standard image formats (JPEG, TIF, 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, particularly fully processed and calibrated images, there is a common, though not required, convention to represent Right Ascension on the first axis with a negative pixel scale, and Declination on the second axis with a positive pixel scale (this is for celestial coordinates; a similar convention exists for galactic coordinates). In this case, such an image would be rendered onto a display starting with the lower left pixel and filling in left to right, bottom to top.



For the AVM WCS convention, as described above, the choice is to define the coordinate grid as one would looking at a piece of graph paper, with the origin at the lower left. This does not follow the byte ordering definition of WCS used by FITS files, but it does have the benefit of yielding WCS solutions that match FITS files following the common convention described here.

This difference in display convention is handled in a variety of ways by different programs resulting in an “image flip” issue that haunts the field of astronomical imaging. Some packages like the FITS Liberator (a FITS import filter for Photoshop) will fill in the image from bottom to top, compensating for the difference in display convention. Other image libraries will simply treat a FITS array like any other image and render its rows from top to bottom, regardless of what WCS information is in the header.

Ultimately there must be some difference in the way WCS is interpreted between FITS and other standard image formats. Fundamentally this is because the FITS array allows for arbitrary ordering of data and the way it is rendered onto a display should be determined the WCS description. Other images are always defined to render top to bottom, regardless of whether there is other orientation metadata embedded in their headers.

The adopted AVM convention does offer two key advantages:

- Follows standard graph conventions for orienting images
- Will lead to matching WCS for a very common FITS convention

The primary disadvantage is largely the burden of programmers:

- Developers must reference array elements of an image (bottom to top) reversed from the way the image is displayed (top to bottom)

6 Appendix D: Metadata Extension: FITS Liberator

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

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

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

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

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

Comment: Some possibilities include: Linear, Logarithmic etc.
FL.StretchFunction: FITS Liberator stretch function

The different possible options for the FITS Liberator stretch function (as of version 2.0; additional stretches may become available in future versions):

- Linear
- Logarithmic
- Square-root
- Inverse hyperbolic sine
- Cube Root
- LogarithmicLogarithmic
- Logarithmic(Square-root)

FL.BackgroundLevel (float, list-ordered)

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

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

FL.PeakLevel (float, list-ordered)

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

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

FL.ScaledBackgroundLevel (float, list-ordered)

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

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

FL.ScaledPeakLevel (float, list-ordered)

Definition: The target upper value of the range of the Scaled image. One **FL.ScaledPeakLevel** per exposure.

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

FL.BlackLevel (float, list-ordered)

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

FL.WhiteLevel (float, list-ordered)

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

FL.CreationNotes (string)

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

7 Appendix E: Example Metadata File

7.1 XMP Example File for NGC 1566 Sample Image

We include all of the extraneous XMP and Photoshop tags for your reference. The following is XMP code exported from Photoshop (Fits Liberator) for the image NGC1566. The sample image file can be found at: http://virtualastronomy.org/avm_metadata.php If you open the image in Photoshop you will see all of the metadata under File Info.

Black text: rubbish tags that get exported with Photoshop
Red text: AVM compliant/equivalent tags
Blue text: metadata

Special Notes: AVM fields 47-50 (**File.Type**, **File.Dimension**, **File.Size**, **File.BitDepth**) are not exported with XMP metadata. At this point in time they need to manually entered, or could be mined from the 'Properties' of the image.


```
<?xpacket begin="" id="W5M0MpCehiHzreSzNTczkc9d"?>
<x:xmpmeta xmlns:x="adobe:ns:meta/" x:xmptk="Adobe XMP Core 4.1-c036 46.276720, Mon Feb 19 2007 22:40:08 ">
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
<rdf:Description rdf:about=""
xmlns:xapMM="http://ns.adobe.com/xap/1.0/mm/"
xmlns:stRef="http://ns.adobe.com/xap/1.0/sType/ResourceRef#">
<xapMM:DocumentID>uuid:1E7F7A4BC769DC11AC88B19DB3434320</xapMM:DocumentID>
<xapMM:InstanceID>uuid:1468E46EFC6CDC1184DCC8A8F3B84D3F</xapMM:InstanceID>
<xapMM:DerivedFrom rdf:parseType="Resource">
<stRef:instanceID>uuid:28E15341693411DCBB9AE8C948D376C0</stRef:instanceID>
<stRef:documentID>uuid:BE7FC9CE384711DCA118970A627AD648</stRef:documentID>
</xapMM:DerivedFrom>
</rdf:Description>
<rdf:Description rdf:about=""
xmlns:xap="http://ns.adobe.com/xap/1.0/">
<xap:CreateDate>2007-09-21T11:22:56+02:00</xap:CreateDate>
<xap:MetadataDate>2007-09-27T15:46:56+02:00</xap:MetadataDate>
<xap:SliderValue>0</xap:SliderValue>
<xap:foo>1</xap:foo>
<xap:ModifyDate>2007-09-27T15:46:56+02:00</xap:ModifyDate>
<xap:CreatorTool>Adobe Photoshop CS3 Windows</xap:CreatorTool>
</rdf:Description>
<rdf:Description rdf:about=""
xmlns:dc="http://purl.org/dc/elements/1.1/">
<dc:format>image/jpeg</dc:format>

<dc:description><rdf:Alt> <rdf:li xml:lang="x-default">This beautiful spiral galaxy NGC 1566, located approximately 60
million light-years away in the constellation Dorado was captured by the Spitzer Infrared Nearby Galaxies Survey (SINGS)
Legacy Project using the telescope's Infrared Array Camera (IRAC).


</rdf:li></rdf:Alt></dc:description>

<dc:subject><rdf:Bag><rdf:li>NGC 1566</rdf:li></rdf:Bag></dc:subject>

<dc:creator><rdf:Seq><rdf:li>Spitzer Science Center</rdf:li></rdf:Seq></dc:creator>

</rdf:Description>
<rdf:Description rdf:about=""
xmlns:photoshop="http://ns.adobe.com/photoshop/1.0/">
<photoshop:ColorMode>3</photoshop:ColorMode>
<photoshop:Source>Spitzer Space Telescope</photoshop:Source>

<photoshop:Credit>NASA/JPL-Caltech</photoshop:Credit>
<photoshop:Headline>NGC 1566</photoshop:Headline>
<photoshop:DateCreated>2005-09-15</photoshop:DateCreated>
```

<photoshop:Source>R.Hurt</photoshop:Source>

<photoshop:History>2007-09-14T16:36:54-07:00	File sig05-013.tif opened
Open	Minbari:Users:hurt:Desktop:Example:sig05-013.tif

File Info
Set File Info of current document	To: file info
Creator Phone: “666-666-6666”
Creator E-mail: “sample@sample.com”

2007-09-14T16:39:31-07:00	File sig05-013.tif saved
2007-09-14T16:41:54-07:00	File sig05-013.tif opened
Open	Minbari:Users:hurt:Desktop:Example:sig05-011.tif

Open	Minbari:Users:hurt:Desktop:Example:sig05-013.tif

File Info
Set File Info of current document	To: file info

2007-09-14T16:42:17-07:00	File sig05-013.tif saved
2007-09-20T17:46:25-07:00	File sig05-013.tif opened
Open	Minbari:Users:hurt:Desktop:sig05-013.tif

Open	Minbari:Users:hurt:Desktop:sig05-011.tif

Select previous document	
File Info
Set File Info of current document	To: file info

2007-09-20T17:50:55-07:00	File sig05-013.tif saved
</photoshop:History>
</rdf:Description>
<rdf:Description rdf:about=""
xmlns:tiff="http://ns.adobe.com/tiff/1.0/">
<tiff:ImageWidth>974</tiff:ImageWidth>
<tiff:ImageLength>974</tiff:ImageLength>
<tiff:Compression>5</tiff:Compression>
<tiff:PhotometricInterpretation>2</tiff:PhotometricInterpretation>
<tiff:Orientation>1</tiff:Orientation>
<tiff:SamplesPerPixel>3</tiff:SamplesPerPixel>
<tiff:PlanarConfiguration>1</tiff:PlanarConfiguration>
<tiff:XResolution>3000000/10000</tiff:XResolution>
<tiff:YResolution>3000000/10000</tiff:YResolution>
<tiff:ResolutionUnit>2</tiff:ResolutionUnit>
<tiff:NativeDigest>256,257,258,259,262,274,277,284,530,531,282,283,296,301,318,319,529,532,306,270,271,272,305,315,33432;0FC32E875D87FD1BB0248F5EBFF2DCD2</tiff:NativeDigest>
<tiff:BitsPerSample>
<rdf:Seq>
<rdf:li>8</rdf:li>
<rdf:li>8</rdf:li>
<rdf:li>8</rdf:li>
</rdf:Seq>
</tiff:BitsPerSample>
</rdf:Description>
<rdf:Description rdf:about=""
xmlns:exif="http://ns.adobe.com/exif/1.0/">
<exif:PixelXDimension>974</exif:PixelXDimension>
<exif:PixelYDimension>974</exif:PixelYDimension>
<exif:ColorSpace>-1</exif:ColorSpace>
<exif:NativeDigest>36864,40960,40961,37121,37122,40962,40963,37510,40964,36867,36868,33434,33437,34850,34852,34855,34856,37377,37378,37379,37380,37381,37382,37383,37384,37385,37386,37396,41483,41484,41486,41487,41488,41492,41493,41495,41728,41729,41730,41985,41986,41987,41988,41989,41990,41991,41992,41993,41994,41995,41996,42016,0,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,22,23,24,25,26,27,28,30;61A35826A6ED7C46025BF3C8B66399B7</exif:NativeDigest>
</rdf:Description>
<rdf:Description rdf:about=""
xmlns:avm="http://www.communicatingastronomy.org/avm/1.0/">

<avm:CreatorURL>http://www.spitzer.caltech.edu</avm:CreatorURL>

<avm:MetadataVersion>1.0</avm:MetadataVersion>

<avm:Image.ProductQuality>Good</avm:Image.ProductQuality>

<avm:ReferenceURL>http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=sig05-013</avm:ReferenceURL>

<avm:Type>Observation</avm:Type>

<avm:ID>sig05-013</avm:ID>

<avm:Spatial.CoordinateFrame>ICRS</avm:Spatial.CoordinateFrame>

<avm:Spatial.Equinox>2000.0</avm:Spatial.Equinox>

<avm:Spatial.CoordsystemProjection>TAN</avm:Spatial.CoordsystemProjection>

<avm:Spatial.Quality>Full</avm:Spatial.Quality>

<avm:Spatial.Rotation>-124.205032386</avm:Spatial.Rotation>

```
<avm:Spatial.Notes>FOV: 12.19 x 12.19 arcminutes; Ref coordinate: 4h20m16.72s -54d55m55.13s; derived from astrometry.net file sig05-013.fits</avm:Spatial.Notes>

<avm:Publisher>Spitzer Space Telescope</avm:Publisher>

<avm:PublisherID>1</avm:PublisherID>

<avm:Subject.Category><rdf:Bag><rdf:li>C.5.1.1</rdf:li><rdf:li>C.5.3.2.2</rdf:li> </rdf:Bag></avm:Subject.Category>

<avm:Facility><rdf:Seq><rdf:li>Spitzer</rdf:li><rdf:li>Spitzer</rdf:li><rdf:li>Spitzer</rdf:li
<rdf:li>Spitzer</rdf:li></rdf:Seq></avm:Facility>

<avm:Instrument><rdf:Seq><rdf:li>IRAC</rdf:li><rdf:li>IRAC</rdf:li><rdf:li>IRAC</rdf:li><rdf:li>IRAC</rdf:li></rdf:Seq></avm:Instrument>

<avm:Spectral.ColorAssignment><rdf:Seq><rdf:li>Blue</rdf:li><rdf:li>Green</rdf:li><rdf:li>Red</rdf:li><rdf:li>Red</rdf:li></rdf:Seq></avm:Spectral.ColorAssignment>

<avm:Spectral.Band><rdf:Seq><rdf:li>Infrared</rdf:li><rdf:li>Infrared</rdf:li><rdf:li>Infrared</rdf:li><rdf:li>Infrared</rdf:li></rdf:Seq></avm:Spectral.Band>

<avm:Spectral.Bandpass><rdf:Seq><rdf:li>Near-Infrared</rdf:li><rdf:li>Near-Infrared</rdf:li><rdf:li>Near-Infrared</rdf:li><rdf:li>Near-Infrared</rdf:li></rdf:Seq></avm:Spectral.Bandpass>

<avm:Spectral.CentralWavelength><rdf:Seq><rdf:li>3600</rdf:li><rdf:li>4500</rdf:li><rdf:li>5800</rdf:li><rdf:li>8000</rdf:li></rdf:Seq></avm:Spectral.CentralWavelength>

<avm:Spatial.ReferenceValue><rdf:Seq><rdf:li>65.0696476555</rdf:li><rdf:li>-54.9319798442</rdf:li></rdf:Seq></avm:Spatial.ReferenceValue>

<avm:Spatial.ReferenceDimension><rdf:Seq><rdf:li>974</rdf:li><rdf:li>974</rdf:li></rdf:Seq></avm:Spatial.ReferenceDimension>

<avm:Spatial.ReferencePixel><rdf:Seq><rdf:li>616.293197632</rdf:li><rdf:li>346.155345917</rdf:li></rdf:Seq></avm:Spatial.ReferencePixel>

<avm:Spatial.Scale><rdf:Seq><rdf:li>-0.000208670950176</rdf:li><rdf:li>0.000208670950176</rdf:li></rdf:Seq></avm:Spatial.Scale>

<avm:Spatial.CDMatrix><rdf:Seq><rdf:li>0.000117</rdf:li><rdf:li>0.000173</rdf:li><rdf:li>0.000173</rdf:li><rdf:li>-0.000117</rdf:li></rdf:Seq></avm:Spatial.CDMatrix>

<avm:Spectral.Notes><rdf:Alt><rdf:li xml:lang="x-default">The SINGS image is a four-channel false-color composite, where blue indicates emission at 3.6 microns, green corresponds to 4.5 microns, and red to 5.8 and 8.0 microns. The contribution from starlight (measured at 3.6 microns) in this picture has been subtracted from the 5.8 and 8 micron images to enhance the visibility of the dust features.</rdf:li></rdf:Alt></avm:Spectral.Notes>

<avm:Temporal.StartTime><rdf:Seq><rdf:li>2002-12-21-0900</rdf:li><rdf:li>2002-12-21-0900</rdf:li><rdf:li>2002-12-21-0900</rdf:li><rdf:li>2002-12-21-0900</rdf:li></rdf:Seq></avm:Temporal.StartTime>

<avm:Temporal.IntegrationTime><rdf:Seq><rdf:li>10</rdf:li><rdf:li>10</rdf:li><rdf:li>10</rdf:li><rdf:li>10</rdf:li></rdf:Seq>
</avm:Temporal.IntegrationTime>
<avm:DatasetID>
<rdf:Seq>
<rdf:li>a1</rdf:li>
<rdf:li>a2</rdf:li>
<rdf:li>a3</rdf:li>
<rdf:li>a4</rdf:li>
</rdf:Seq>
</avm:DatasetID>
<avm:ResourceID>
<rdf:Seq>
<rdf:li>http://web.ipac.caltech.edu</rdf:li>
</rdf:Seq>
</avm:ResourceID>
</rdf:Description>
<rdf:Description rdf:about=""
xmlns:illustrator="http://ns.adobe.com/illustrator/1.0/">
<illustrator:StartupProfile>Print</illustrator:StartupProfile>
</rdf:Description>
<rdf:Description rdf:about=""
```

```
xmlns:Iptc4xmpCore="http://iptc.org/std/Iptc4xmpCore/1.0/xmlns/">
<Iptc4xmpCore:CreatorContactInfo rdf:parseType="Resource">
<Iptc4xmpCore:CiAdrExtadr>1200 E. California Blvd.</Iptc4xmpCore:CiAdrExtadr>
<Iptc4xmpCore:CiAdrCity>Pasadena</Iptc4xmpCore:CiAdrCity>
<Iptc4xmpCore:CiAdrRegion>CA</Iptc4xmpCore:CiAdrRegion>
<Iptc4xmpCore:CiAdrPcode>91125</Iptc4xmpCore:CiAdrPcode>
<Iptc4xmpCore:CiAdrCtry>USA</Iptc4xmpCore:CiAdrCtry>
 <Iptc4xmpCore:CiEmailWork>example@ipac.caltech.edu</Iptc4xmpCore:CiEmailWork>
<Iptc4xmpCore:CiTelWork>555-555-5555</Iptc4xmpCore:CiTelWork>
</Iptc4xmpCore:CreatorContactInfo>
</rdf:Description>
<rdf:Description rdf:about=""
xmlns:xapRights="http://ns.adobe.com/xap/1.0/rights/">
<xapRights:UsageTerms>
<rdf:Alt>
<rdf:li xml:lang="x-default">Public Domain</rdf:li>
</rdf:Alt>
</xapRights:UsageTerms>
</rdf:Description>
</rdf:RDF>
</x:xmpmeta>
<?xpacket end="w"?>
```

7.2 AVM to VOTable translation XML file specific to VAMP Case Study: Stellarium

VAMP is currently working on a "proof of concept" using Stellarium[14] to test the viability of the AVM tags. Stellarium[15] is a night sky visualization program. For our proof of concept, we are employing the VirGO module which can overlay DSS images and star catalogs onto a grid in the sky. With these tools, it is easy to determine if the WCS tags are functioning correctly. Future development with Stellarium may include a VAMP module. This module will allow the contextual information (like Headline and description) to be shown alongside the image on the sky.

The example below showcases an AVM to VOTable (Stellarium specified) translation layer.

Grey text:	base XML tags/syntax
Red text:	AVM compliant/equivalent tags
Green text:	UCD1 tag (UCD version 1.1 compliant)
Blue text:	metadata

```
<?xml version="1.0" encoding="UTF-8"?>
<VOTABLE xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" version="1.1"
xmlns="http://www.ivoa.net/xml/VOTable/v1.1" xsi:schemaLocation="http://www.ivoa.net/xml/VOTable/v1.1
http://www.ivoa.net/xml/VOTable/v1.1">
<RESOURCE type="results">

<DESCRIPTION> Astronomy Visualization Metadata (AVM) translated into VOTable format for use in Stellarium/VirGO
application. See: http://www.virtualastronomy.org
Not every AVM tag currently corresponds to a UCD1 or UCD1+ tag.</DESCRIPTION>

<INFO name="QUERY_STATUS" value="OK"></INFO>

<TABLE>
<FIELD ID="MetadataVersion" datatype="char" arraysize="*"/>
<FIELD ID="Creator" ucd="meta.curation" datatype="char" arraysize="*"/>
<FIELD ID="CreatorURL" datatype="char" arraysize="*"/>
<FIELD ID="Contact.Name" datatype="char" arraysize="*"/>
```

[14] http://www.stellarium.org/
[15] http://www.stellarium.org/

```
<FIELD ID="Contact.Email" ucd="meta.email" datatype="char" arraysize="*"/>
<FIELD ID="Contact.Telephone" datatype="char" arraysize="*"/>
<FIELD ID="Contact.Address" datatype="char" arraysize="*"/>
<FIELD ID="Contact.City" datatype="char" arraysize="*"/>
<FIELD ID="Contact.StateProvince" datatype="char" arraysize="*"/>
<FIELD ID="Contact.PostalCode" datatype="char" arraysize="*"/>
<FIELD ID="Contact.Country" datatype="char" arraysize="*"/>
<FIELD ID="Rights" datatype="char" arraysize="*"/>
<FIELD ID="Headline" ucd="meta.title" datatype="char" arraysize="*"/>
<FIELD ID="Subject.Category" ucd="meta.code.class" datatype="char" arraysize="*"/>
<FIELD ID="Subject.Name" ucd="meta.id" datatype="char" arraysize="*"/>
<FIELD ID="Description" ucd="meta.abstract" datatype="char" arraysize="*"/>
<FIELD ID="ReferenceURL" ucd="meta.ref.url" datatype="char" arraysize="*"/>
<FIELD ID="Credit" ucd="meta.curation" datatype="char" arraysize="*"/>
<FIELD ID="Date" ucd="time.release" datatype="char" arraysize="*"/>
<FIELD ID="ID" ucd="meta.id" datatype="char" arraysize="*"/>
<FIELD ID="Type" datatype="char" arraysize="*"/>
<FIELD ID="Image.ProductQuality" ucd="meta.code.qual" datatype="char" arraysize="*"/>
<FIELD ID="Facility" name="Telescope Name" ucd="instr.tel" datatype="char" arraysize="*"/>
<FIELD ID="Instrument" name="Instrument Name" ucd="instr" datatype="char" arraysize="*"/>
<FIELD ID="Spectral.ColorAssignment" dataype="char" arraysize="*"/>
<FIELD ID="Spectral.Band" datatype="char" arraysize="*"/>
<FIELD name="Spectral.Bandpass" ucd="instr.bandpass" datatype="char" arraysize="*">
 <DESCRIPTION>Bandpass by name</DESCRIPTION>
 <!-- Possible derivation from AVM 27 Spectral.Bandpass: For color composites set to "RGB" -->
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<!-- Begin VirGO Requirements -->
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 <!-- No AVM translations: The program should assume the Ra and Dec refers to the reference pixel-->
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 <!-- No AVM translation: VirGO requires a JMD to display image -->
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 <!-- No AVM translation: VirGO requires data field to be set to "preview" for display of image-->
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 <!-- No AVM translation: VirGO improves the display of information if set to "IMAGE" -->
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	<TD> http://www.spitzer.caltech.edu </TD>
	<TD>R.Hurt</TD>
	<TD>example@ipac.caltech.edu </TD>
	<TD>555-555-5555 </TD>
	<TD>1200 E. California Blvd. </TD>
	<TD>Pasadena </TD>
	<TD>CA </TD>
	<TD>91125 </TD>
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	<TD> C.5.1.1 C.5.3.2.2 </TD>
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	<TD>This beautiful spiral galaxy NGC 1566, located approximately 60 million light-years away in the
constellation Dorado was captured by the Spitzer Infrared Nearby Galaxies Survey (SINGS) Legacy Project using the
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astrometry.net file sig05-013.fits</TD>
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