



International

Virtual

Observatory

Alliance

Photometry Data Model

Version 0.2

Working Draft 2010 November 29

This version:

WD-PHOTDM-0.2-20101129

Latest version:

<http://www.ivoa.net/Documents/latest/latest-version-name>

Previous version(s):

Editor(s):

Jesus Salgado
Pedro Osuna

Author(s):

Jesus Salgado
Carlos Rodrigo
Pedro Osuna
Deborah Baines
Mireille Louys
Evanthia Hatziminaoglou
Mark Allen

Abstract

We describe photometry data, photometry filters and magnitudes through a simple DM in order to allow the creation of protocols to access photometric data in magnitudes. This can be used through SSAP or any other protocol utype

based. Connections to other IVOA data models like Spectral DM, Characterization and Physical Quantity are also reflected in the document.

Status of This Document

The first release of this document was 2010 May 05.

This is an IVOA Note expressing suggestions from and opinions of the authors. It is intended to share best practices, possible approaches, or other perspectives on interoperability with the Virtual Observatory. It should not be referenced or otherwise interpreted as a standard specification.

A list of [current IVOA Recommendations and other technical documents](http://www.ivoa.net/Documents/) can be found at <http://www.ivoa.net/Documents/>.

Acknowledgements

“Ack here, if any”

Contents

1	Introduction	3
2	Astronomical Photometry	4
3	Photometry Data Model	5
3.1	PhotometricSystem	7
3.1.1	PhotometricSystem.description: String	7
3.1.2	PhotometricSystem.detectorType: int	8
3.2	PhotometryFilter Class	8
3.2.1	PhotometryFilter.uniqueIdentifier: String	8
3.2.2	PhotometryFilter.fpsIdentifier: String	8
3.2.3	PhotometryFilter.filterName: String	9
3.2.4	PhotometryFilter.filterDescription: String	9
3.2.5	PhotometryFilter.SpectralAxis	9
3.2.6	PhotometryFilter.TimeAxis: IVOA.Char.TimeAxis	11
3.2.7	PhotometryFilter.transmissionCurve: IVOA.SpectralDM	12
3.3	ZeroPoint class	13
3.3.1	ZeroPoint.uniqueIdentifier: String	13
3.3.2	ZeroPoint.zeroPointFlux: IVOA.PhysicalQuantity	13
3.3.3	ZeroPoint.photometryFilter: PhotometryFilter	14
3.3.4	ZeroPoint.magnitudeSystem: MagnitudeSystem	14
3.3.5	ZeroPoint.type: integer	14
3.4	AsinhZeroPoint	15

3.4.1	AsinhZeroPoint.softeningParameter: double	15
3.5	MagnitudeSystem	15
3.5.1	MagnitudeSystem.type: String	16
3.5.2	MagnitudeSystem.referenceSpectrum: IVOA.SpectralDM	16
3.6	PhotometryPoint	16
3.6.1	PhotometryPoint.Value: IVOA.DoublePhysicalQuantity	17
3.6.2	PhotometryPoint.zeropoint: ZeroPoint.uniqueIdentifier	17
4	Use Cases	17
4.1	Conversion from magnitude to flux, using a Filter Profile Service	17
5	Appendix	18
5.1	Zero point magnitude and zero point flux	18
5.2	Interrelation between Pogson and Asinh magnitudes	19
	References	20

1 Introduction

A key role of the VO is to facilitate finding data and combining them in a scientifically meaningful way. An example of usage of such an assembly of data is the construction of the spectral energy distribution (SED) of astrophysical sources from data at different wavelengths, that give the astronomer a glimpse on the underlying physical processes. The construction of an SED requires that photometric data be described in a standard way. This note proposes a data model that describes photometric measurements, and outlines how such measurements could be made available through the Simple Spectral Access Protocol (SSAP) or Table Access Protocol (TAP) services so that the photometric measurements can be used and combined in scientific software tools.

In order to construct an SED, all that is required is the measured flux densities and associated errors, and the wavelength and bandwidth for each such point. Many of the catalogues already available in the VO contain these measurements and there is much to be gained by enabling photometric data from different catalogues to be combined. Due mostly to historic reasons, many measurements available in catalogues are expressed in magnitudes in various filter systems, so an important part of the proposed photometry data model focuses on the description of the filter and magnitude systems with sufficient information for making the transformation of magnitudes into flux densities.

The proposed model is based on the filter transmission curves (or system throughput) of a photometric system, source-independent values of the average wavelength and width at half maximum (bandwidth), and a photometric zero point, necessary for the conversion of magnitudes to flux densities. While the description of photometric systems and photometric measurements can be more complex than this, the proposed model is intended to describe these basic properties in order to support some simple SED use cases. More detailed descriptions are envisaged to be developed within the characterisation data

model, and may eventually be able to support use cases requiring higher level of accuracy.

In this note we first summarize the key points about astronomical photometry (section 2). We then provide a detailed structure and elements of the proposed model (section 3). Section (4) describes use cases in which the model description could be used in making photometry data available through VO protocols, and, very briefly how, scientific tools could use this information.

2 Astronomical Photometry

In astronomy, photometry refers to measuring the brightness, flux or intensity an astrophysical object. Usually, photometry refers to measurement of radiation taken within broad wavelength bands. A set of well defined band-passes (or filters) with a known sensitivity to incident radiation is called a photometric system. Because of historical and practical reasons, photometric data is not stored in flux format but in magnitudes. Expressing fluxes in terms of photometric magnitudes, can be considered as a shortcut to expressing ratios of fluxes. For two stars with flux f_1 and f_2 , their magnitude difference can be expressed as:

$$m_1 - m_2 = -2.5 \log_{10}(f_1 / f_2)$$

Note: We will use the standard and common Pogson magnitudes conversion formulae. See ZeroPoint.type field description in the text.

A colour index for an object can be defined as e.g.

$$B - V = m_B - m_V$$

where m_B and m_V are the B and V magnitudes of the object, respectively.

Although some filters are considered standard, a certain implementation of a filter in a certain telescope can be close to, but vary from, the standard values. Apart from the band-pass covered by the filter, real filters are not ideal-square filters, i.e., the response over a wavelength range, $\Delta\lambda$, is not 100% over the entire band-pass. Furthermore, detectors detect only a fraction of the incident photons. As a result, all filters have an associated transmission curve that describes the fraction of detected per incident photons, taking into account all the elements along the optical path. Aperture corrections are described in the IVOA Spectral DM.

In order to calibrate the measurements and convert them into physical units, known objects with well known emission in the relevant parts of the electromagnetic spectrum are observed with the same configuration (detector+filter). This produces a certain flux measurement which for this astronomical object can be considered as the reference magnitude. Then:

$$m - m_{reference} = -2.5 \log_{10}(f / f_{reference})$$

hence

$$f = f_{reference} 10^{\frac{m - m_{reference}}{2.5}}$$

where f and m are the flux and magnitude, respectively, of the observed source, and $f_{reference}$ and $m_{reference}$ are the flux and magnitude, respectively, of the calibration source. If one expresses the flux as a function of the flux of a source that is considered to have zero magnitude, the equation would be:

$$f = f^0 10^{-\frac{m}{2.5}}$$

where f^0 is now called the zero point flux.

When the reference spectrum is that of Vega, which has, by default, a magnitude of exactly 0.00 at all wavelengths and in all filters (this is not fully true in modern astronomy, where Vega has a magnitude of 0.03 and the calculation of the zero point is done through an average of the magnitudes of a set of well-known standard stars), the resulting magnitudes are said to be expressed in the Vega magnitude system.

In other photometric systems, the spectrum used to express the characterization could be a synthetic one, e.g. for the AB magnitude system a flux:

$$f_{AB,v}^0 = 3.63 \times 10^{-20} \text{ erg} \cdot \text{s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$$

that produces a magnitude zero in all the bands for this photometric system or STMag systems where the reference flux would be a monochromatic f_{λ} flux:

$$f_{ST,\lambda}^0 = 3.631 \times 10^{-9} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$$

3 Photometry Data Model

The following Data Model describes a photometry filters, photometric systems, magnitude systems, zero points and its interrelation with the other IVOA data models.

The main class in this diagram is Photometry Filter. This class contains all the attributes necessary to describe a filter from the data discovery point of view. Other general attributes to characterize the filter would be done through the IVOA Characterization Data Model.

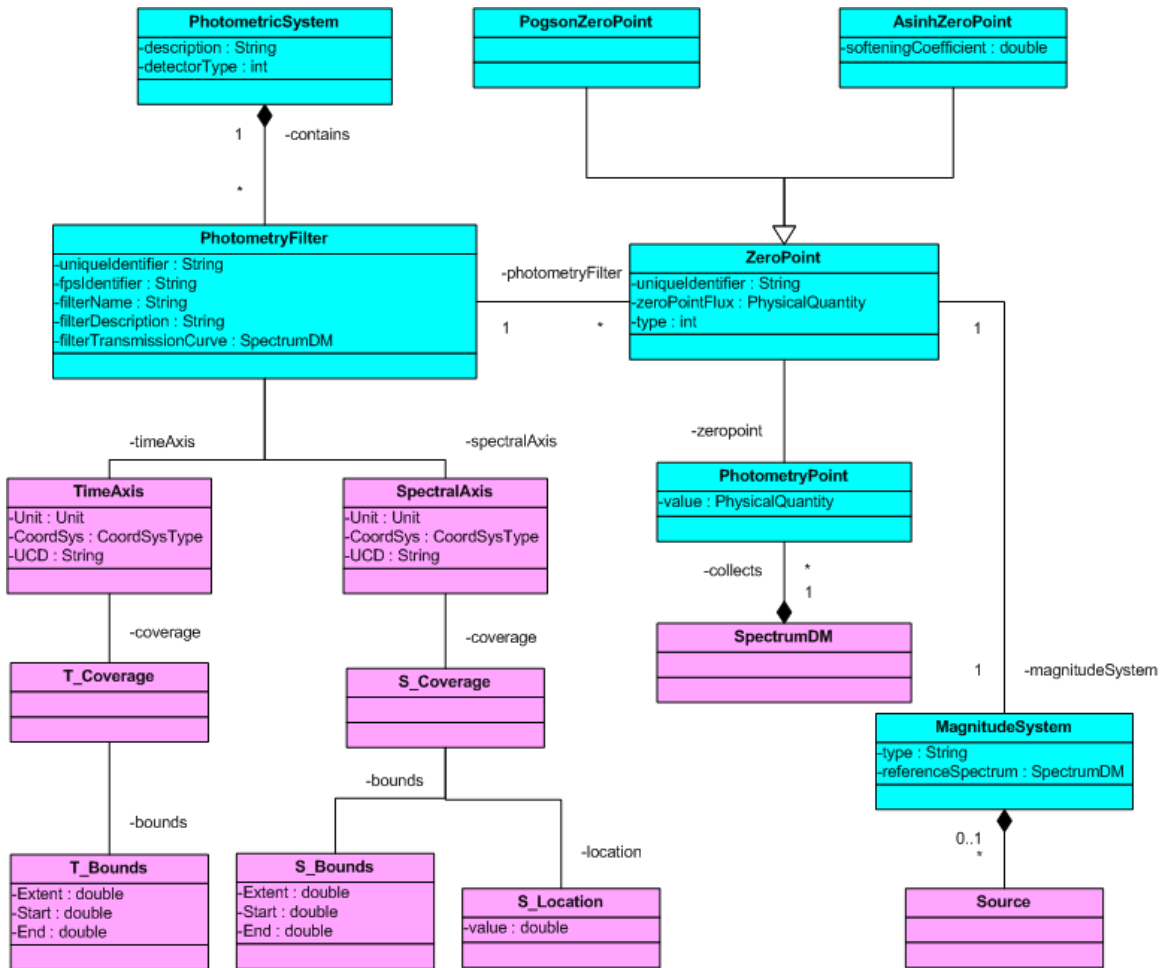
A Photometric System is considered a container of Photometry Filters usually as belonging to the same observatory/telescope or because it belongs to the same standard system.

A magnitude system is characterized for a certain reference spectrum that will produce a certain zero point for a certain photometry filter. This reference spectrum could be an ideal one (as in STmag and ABmag systems), a Vega-like spectrum (as in Vegamag systems) (please notice that different Vega spectrum versions have been historically used) or any other. In many cases, the reference spectrum has been calculated as an average of spectrum from several astronomical objects spectra. This would be characterized by a set of Source instances.

A zero point would be then a flux value that can be considered as zero magnitude, so its value will allow conversions from fluxes to magnitudes and the other way around. It has associated a photometry filter and it also depends on the magnitude system (reference spectrum) used to calculate this magnitude.

An intermediate class, Photometry Point, connects Zero Point class and SpectralDM, allowing the handling of photometric data through e.g. SSAP or TAP services.

A Spectrum would contain a set of photometry points and every point will be characterized by a Zero Point and from this object, to a certain photometry filter and photometric system. Using this information, magnitudes from different photometric systems could be compared between them or compared to spectroscopic data in flux.



In order to fully describe values of the magnitudes inside photometry point instances, we use the IVOA Physical Quantity classes. In general, all the magnitudes that have units and could have errors associated are considered of type Physical Quantity.

3.1 PhotometricSystem

This class briefly describes the photometric system that contains a set of photometry filters. Photometry filters can be contained in a certain photometric systems as part of the same observatory/telescope or as part of a known system.

3.1.1 PhotometricSystem.description: String

Human readable string representation of the photometric system. This will allow client applications the display of information to final user.

Examples:

```

Sloan
Johnson
  
```

3.1.2 PhotometricSystem.detectorType: int

Detector type associated to this photometric system. Possible values are:

Type of detector	Value	Examples
Energy Counter	0 (default)	Energy amplifiers devices
Photon Counter	1	CCDs or photomultipliers

This will be used in order to decide how to calculate the flux average in, e.g., synthetic photometry calculations. At current state, this list is exhaustive. See photometry filter transmission curve description to understand how to use this field.

3.2 PhotometryFilter Class

This is the main class that describes a photometry filter.

3.2.1 PhotometryFilter.uniquelIdentifier: String

This field identifies, in a unique way, within a certain Photometry Filter Profile service, a filter. Although the main requirement of the uniquelIdentifier is to be unique within a Filter Profile Service, the suggested syntax would be:

```
[Observatory]/[Band] /[Detector]/[Suffix]
```

Where Suffix is optional metadata added to the uniquelIdentifier string to ensure uniqueness within a Filter Profile Service.

Example:

```
SDSS/G/SDSS.G
```

3.2.2 PhotometryFilter.fpsIdentifier: String

IVOA identifier of the filter profile service where this photometry filter is registered to be used in the discovery of all the relevant photometry filter properties

The syntax of this identifier, as any other IVOA identifier, should be as follows:

```
ivo ://<ivoa authority id>/resource key>
```

Example:

```
ivo://svo/fps
```

where svo is the authority id, fps is the resource key of the service.

The service url of the filter profile service would be obtained from the registry by requesting the associated information of this registry resource.

3.2.3 PhotometryFilter.filterName: String

Human readable string representation of the filter name. This will allow client applications to display of information to the final user.

Example:

```
SDSS.G
```

3.2.4 PhotometryFilter.filterDescription: String

Verbose human readable string description of the filter. This will allow client applications to display of information to the final user.

3.2.5 PhotometryFilter.SpectralAxis

This spectral axis object associated to a photometry filter describe the spectral coverage of the band for this filter. See IVOA Characterization DM for further description.

3.2.5.1 PhotometryFilter.SpectralAxis.Unit: IVOA.Unit

Global unit description for all the magnitudes of this spectral axis description. All the magnitudes in this axis must share these units.

3.2.5.2 PhotometryFilter.SpectralAxis.UCD: String

UCD that characterize the spectral axis characterization of the filter. All the relevant spectral axis coverage will share this UCD.

Example:

```
em.wl
```

3.2.5.3 PhotometryFilter.SpectralAxis.Coverage.Location: Char.SpectralAxis.Coverage.Location

The spectral axis coverage of the referenced photometry filter. Although this will reuse the Char.SpectralAxis.Coverage.Location element of the Characterization Data Model, the basic elements of this object are described within the context of a photometry filter as follows.

3.2.5.4 PhotometryFilter.SpectralAxis.Coverage.Location.Value: double

A spectral coordinate value that can be considered by the data provider as the more representative for this specific filter band-pass. The selection of this value should take into account the filter transmission curve profile and in general should be close to the wavelength mean value, defined as:

$$\lambda_{mean} = \frac{\int T(\lambda)\lambda d\lambda}{\int T(\lambda)d\lambda}$$

where λ_{mean} is the spectral bounds mean value, $T(\lambda)$ is the transmission curve (see below), λ is the wavelength. Please notice that, although the integrals are defined in all the spectral axis and, as the transmission curve will be only defined in a spectral range, the integrals will be really defined in this spectral range.

3.2.5.5 PhotometryFilter.SpectralAxis.Coverage.Bounds.Extent: double

For square filters (100% between the minimum and maximum wavelength and 0% otherwise), the bandwidth could be described as $\lambda_{max} - \lambda_{min}$.

However, for real filters, the bandwidth is not very usable to describe the band-pass of the filter, but the effective width, that can be described as follow:

$$w = \frac{\int T(\lambda)d\lambda}{Max(T(\lambda))}$$

Where w is the effective width, $T(\lambda)$ is the transmission curve (see below) and $Max(T(\lambda))$ the maximum value of the transmission curve. As in previous point, please notice that, although the integrals are defined in all the spectral axis and, as the transmission curve will be only defined in a spectral range, the integrals will be really defined in this spectral range.

3.2.5.6 PhotometryFilter.SpectralAxis.Coverage.Bounds.Start: double

Also called λ_{min} in the rest of the document, is a spectral value that better describes the minimum value of the spectral range of the filter band-pass. In general, although this not will be imposed in order to allow a better description for different types of transmission curves, this quantity will be close to:

$$\lambda_{\min} = \lambda_{\text{mean}} - \frac{W}{2}$$

In practice, this could be taken as the minimum value of the filter transmission curve.

3.2.5.7 PhotometryFilter.SpectralAxis.Coverage.Bounds.Stop: double

Also called λ_{\max} in the rest of the document, is a spectral value that better describes the maximum value of the spectral range of the filter band-pass. In general, although this not will be imposed in order to allow a better description for different types of transmission curves, this quantity will be close to:

$$\lambda_{\max} = \lambda_{\text{mean}} + \frac{W}{2}$$

In practice, this could be taken as the maximum value of the filter transmission curve.

3.2.6 PhotometryFilter.TimeAxis: IVOA.Char.TimeAxis

Time axis associated to this photometry filter. This will be used to characterize the validity range of this specific photometry filter configuration. This is particularly useful for ground base telescopes where filter, electronics, etc could easily change generating versions of the same photometry filter. See IVOA Characterization DM for further description.

3.2.6.1 PhotometryFilter.TimeAxis.Coverage.Bounds: IVOA.Char.TimeAxis.Coverage.Bounds

Typically, some telescope filters change in properties with time, e.g. due to improvements in the filter by substitution of physical parts or because of changes in the sensitivity. However, filters preserve the same name. In order to better characterize these kinds of situations, a time range can be defined.

3.2.6.1.1 PhotometryFilter.TimeAxis.Coverage.Bounds.Start: ISOTime

Start time of the time coverage when this filter configuration is applicable. String time format accepted, ISO8601:

```
YYYY-MM-DD[T[hh[:mm[:ss[.s[TZD]]]]]]
```

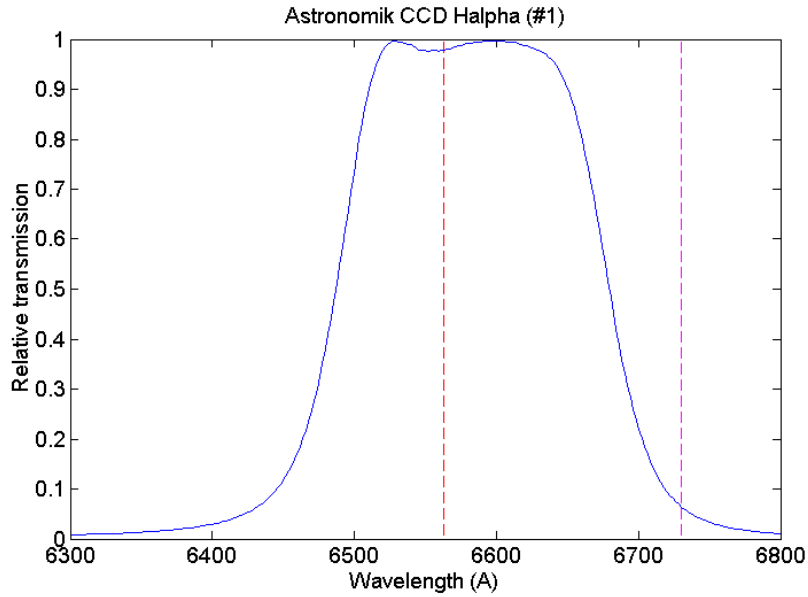
3.2.6.1.2 PhotometryFilter.TimeAxis.Coverage.Bounds.Stop: ISOTime

End time of the time coverage when this filter configuration is applicable. String time format accepted, ISO8601:

```
YYYY-MM-DD[T[hh[:mm[:ss[.s[TZD]]]]]]
```

3.2.7 PhotometryFilter.transmissionCurve: IVOA.SpectralDM

Effective transmission curve is a 2-D graph that describes the transmission properties of the filter over a wavelength range defined by the filter bandpass. It is composed by a spectral coordinate in the x-axis and a scalar in the y-axis. This effective response curve encloses all the possible components that modifies the energy/photon collection.



This curve can be used, e.g. for the creation of synthetic photometry from a observational or a theoretical spectrum by applying it to the spectrum in the filter band-pass. Taking as input a certain flux, the effective flux as seen using a certain filter would be, for energy counters:

$$f(\lambda_{eff}) = \frac{\int T(\lambda)f(\lambda)d\lambda}{\int T(\lambda)d\lambda}$$

And for photon counters (like CCDs or photomultipliers):

$$f(\lambda_{eff}) = \frac{\int T(\lambda)f(\lambda)\lambda d\lambda}{\int T(\lambda)\lambda d\lambda}$$

Where $T(\lambda)$ is the transmission curve, $f(\lambda)$ is the flux of the spectrum. As the transmission curve is defined only in the filter band-pass, the limits of the integrals will be the spectral range where the transmission curve is defined.

The transmission curve is not really a spectrum, however, and in order to gain profit from the definition of spectral coordinate axes in the IVOA Spectrum Data Model, the type of this curve will be spectrum.

3.3 ZeroPoint class

This class is used to characterize a zero point flux obtained during the calibration of a certain photometry filter on a certain photometric system configuration. This object includes references to the relevant Photometric System and Photometry Filter objects.

3.3.1 ZeroPoint.uniqueIdentifier: String

This field identifies, in a unique way, within a certain Photometry Filter Profile service, a zero point assigned to a filter and a certain photometric system type. Although the main requirement of the uniqueIdentifier is to be unique within a Filter Profile Service, the suggested syntax would be:

```
[Observatory]/[Band] /[Detector]/[Photometric System Type]/[Suffix]
```

Where Suffix is optional metadata added to the uniqueIdentifier string to ensure uniqueness within a Filter Profile Service. Please notice the suggested zero point unique identifier syntax corresponds with the Photometry Filter unique identifier + the photometric system type.

Example:

```
SDSS/G/SDSS.G/AB
```

3.3.2 ZeroPoint.zeroPointFlux: IVOA.PhysicalQuantity

Flux of an astronomical object that produces a magnitude=0 for this particular filter and photometric system. This quantity is necessary to convert to flux a certain magnitude.

For Pogson magnitudes (see section 3.2.5) it will be used in the following way:

$$f = f^0 10^{-m/2.5}$$

See ZeroPoint.type description for other definitions.

The flux could be expressed as f_λ or f_ν , leaving the characterization of the type of flux to the units in which this quantity is expressed.

3.3.3 ZeroPoint.photometryFilter: PhotometryFilter

Reference to the photometry filter associated to this zero point.

3.3.4 ZeroPoint.magnitudeSystem: MagnitudeSystem

Reference to the magnitude system associated to this zero point.

3.3.5 ZeroPoint.type: integer

Usual definition of magnitudes, also called Pogson magnitudes, can be improved for faint sources by replacing the usual logarithm with an inverse hyperbolic sine function. This kind of magnitudes are called “ashin magnitudes” or “luptitudes” [9]

Zero point type	Value	Description
Pogson	0 (default)	Usual definition
Asinh	1	Used for faint sources, replacing the usual logarithm with an inverse hyperbolic sine function.

The main difference between the two zero point type is the conversion formulae to be used.

For Pogson magnitudes, the usual definition should be used:

$$\frac{f}{f_0} = 10^{-m/2.5}$$

For asinh magnitudes, the definition would change by:

$$\frac{f}{f_0} = 10^{-m/2.5} [1 - b^2 \cdot 10^{2m/2.5}]$$

Where f is the flux of the observed source, f_0 is the zero point flux value, m is the magnitude assigned to this source and a new parameter appears, b , called softening parameter which value will be referenced in this data model as `AsihnZeroPoint.softeningParameter`.

To calculate magnitudes from fluxes the inverse formulae to be used for Pogson magnitudes is:

$$m = -2.5 \log\left(\frac{f}{f_0}\right)$$

And for asinh magnitudes:

$$m = \frac{-2.5}{\ln(10)} \left[\sinh^{-1}\left(\frac{f}{2bf_0}\right) + \ln(b) \right]$$

It can be seen that Pogson and Asinh magnitudes are the same if $b=0$ although, numerically it is recommended to use different equations to prevent infinities. See Appendix 5.2

3.4 AsinhZeroPoint

Extension of zero point object to accommodate extra information needed to describe extra fields needed for magnitude to flux conversions and vice versa,

3.4.1 AsinhZeroPoint.softeningParameter: double

Parameter used to correct the calculation of magnitudes for faint sources. Usually called b . See [9] for a formal explanation.

Example:

Values used for SDSS DR5 asinh magnitudes:	
Band	Softening Parameters (b coefficients)
U	1.4×10^{-10}
G	0.9×10^{-10}
R	1.2×10^{-10}
I	1.8×10^{-10}
Z	7.4×10^{-10}

3.5 MagnitudeSystem

Main difference between magnitude systems is the reference spectrum used to evaluate the magnitudes. In some occasions, the magnitude system will have a real spectrum of an existing source to calibrate all the magnitudes. In other occasions, a synthetic spectrum will be used.

3.5.1 MagnitudeSystem.type: String

Photometric system type used to calculate the associated zero point. Possible values are:

Photometric System Type
VEGmag
ABMag
STMag

The list could be not exhaustive. The principal difference between these photometric systems is the reference spectrum used to calculate the zero point. See section 2.2.3 for a detail description.

3.5.2 MagnitudeSystem.referenceSpectrum: IVOA.SpectralDM

Reference spectrum used by the photometric system. Although this field try to cover the different possible photometric systems in a general way. Some typical types of photometric systems are:

- VEGmag: Makes use of Vega (α Lyr) as the primary calibrating star. PhotometricSystem.referenceSpectrum would be the Vega SED
- ABmag: Makes use of a reference spectrum of constant flux density per unit frequency:

$$f_{AB,\nu}^0 = 3.631 \times 10^{-20} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$$

- STmag: Introduced by the HST Team, makes use of a reference spectrum of constant flux density per unit of wavelength:

$$f_{ST,\lambda}^0 = 3.631 \times 10^{-9} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$$

This list is not exhaustive.

3.6 PhotometryPoint

This class describes observational values in magnitudes of a certain observation. As magnitudes have real meaning in relation of a photometric filter, this class contains the magnitude itself and a reference to the associated filter.

3.6.1 PhotometryPoint.Value: IVOA.DoublePhysicalQuantity

Magnitude obtained during a certain observation of a certain object with a certain photometry filter. This quantity should be calibrated in a way that specific observational specific effects such as atmospheric absorption, sky brightness, etc must have already been corrected for.

This field can be considered close to **Spectrum.Data.FluxAxis.Value** although as it reuses the IVOA.DoublePhysicalQuantity it will already contain value, accuracy, units and UCD.

3.6.2 PhotometryPoint.zeropoint: ZeroPoint.uniqueIdentifier

Reference to the filter used to take the measurement. This field will connect a certain photometry point to the zeroPoint instance and, from it to the relevant zeroPointFlux, photometry filter and magnitude system that produced the measurement, characterizing it and allowing a client application to produce automatic conversions.

4 Use Cases

4.1 Conversion from magnitude to flux, using a Filter Profile Service

The following fields are the minimal information needed in a DAL service response (SSAP or TAP) or into a serialization of the magnitude information in a catalog in order to allow the conversion from magnitudes to fluxes if a filter profile service is used:

- It MUST have one field with utype="PhotometryPoint.Value.value" and UCD="phot.mag" by measurement that includes the magnitude associated to this measurement. Other attributes of PhysicalQuantity like PhotometryPoint.Value.error could be present in the response.
- It MUST have one field per catalog or measurement with utype="ZeroPoint.uniqueIdentifier" that includes the identifier within the filter profile service of the filter and zero point used to take this measurement
- It MUST have one field per catalog or measurement with utype="PhotometryFilter.fpsIdentifier" that describes the IVOA identifier of the filter profile service where this filter is registered

The normal workflow used by an application to do the conversion would be:

- Go to the registry to obtain registration details of the Filter Profile service, using the IVOA identifier. In particular, the service URL of the service will be used to query this service using the uniqueIdentifier.
- Query the Filter Profile Service to obtain basic information of this filter. This information would be, at least:

- ZeroPoint.zeroPointFlux.value
- ZeroPoint.zeroPointFlux.units
- ZeroPoint.type
- PhotometryFilter.SpectralAxis.Coverage.Location.Value

And optionally, any other information that could be used for a better use of the selected data, as, e.g. the Photometry Filter related information.

Please notice that all the information of the Filter Profile Service can be overwritten either in the DAL service or in the data serialization. As an example, it could be decided that the zeroPointFlux to be used was not the general one for this filter within the filter profile service but the night one. In this case, this corrected value would appear in the DAL response or in the data serialization so this value, and not the one on the FPS will be used for the conversions.

Flux could be then calculated as (for Pogson magnitudes, i.e. Zeropoint.type=0)

$$f = f^0 10^{-m/2.5}$$

Where f^0 is the ZeroPoint.zeroPointFlux.value, m is the magnitude associated to the measurement and f is the associated flux. The type of flux (f_λ or f_ν) and the associated units, although they can be indirectly deduced from the field PhotometricSystem.type, they will be the same of the ones for the PhotometryFilter.zeroPoint

In case Zeropoint.type=2 (asinh magnitudes) the value of AsinhZeroPoint.softeningParameter.value should also be used to modify the conversion formula to:

$$f = f^0 10^{-m/2.5} [1 - b^2 \cdot 10^{2m/2.5}]$$

5 Appendix

5.1 Zero point magnitude and zero point flux

The zero point flux can also be interpreted as a magnitude in the following way. Taking the previous equation and clearing the magnitude:

$$m = -2.5 \log_{10}(f / f^0) = -2.5 \log_{10}(f) + 2.5 \log_{10}(f^0) = -2.5 \log_{10}(f) + m_0$$

Where we have defined m_0 , zero point magnitude, as the magnitude associated to the zero point flux:

$$m_0 = 2.5 \log_{10}(f^0)$$

e.g. for ABmag photometric systems, the magnitudes are usually defined as:

$$m_{AB,v} = -2.5 \log_{10}(f_v) - 48.6$$

What is consistent with the definition of a zero point flux of the monochromatic flux:

$$f_{AB,v}^0 = 3.63 \times 10^{-20} \text{ erg} \cdot \text{s}^{-1} \text{ cm}^{-2} \text{ Hz}^{-1}$$

As:

$$m_0 = 2.5 \log_{10}(f_v^0) = 2.5 \log_{10}(3.63 \times 10^{-20}) = -48.6$$

Other systems usually define the zero point flux as a f_λ flux, as it is usually done by, e.g., STMag systems. For these systems, the reference flux would be a monochromatic f_λ flux:

$$f_{ST,\lambda}^0 = 3.631 \times 10^{-9} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$$

The usual definition of magnitudes for this photometric system is:

$$m_{ST,\lambda} = -2.5 \log_{10}(f_\lambda) - 21.1$$

Which corresponds to, as in the previous example, with a zero point flux of

$$f_{ST,\lambda}^0 = 3.631 \times 10^{-9} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$$

as:

$$m_0 = 2.5 \log_{10}(f_\lambda^0) = 2.5 \log_{10}(3.63 \times 10^{-9}) = -21.1$$

In the present model and in order to provide a uniform treatment for all the different photometric systems, we have used the zero point flux as the quantity to characterize the photometry filter. The type of flux (f_v or f_λ) and the units of any converted to flux magnitude would coincide with the ones used to express the zero point flux, i.e., the zero point flux contains information lost in the zero point magnitude.

5.2 Interrelation between Pogson and Asinh magnitudes

It can be proved that, if $b=0$, Pogson and Asinh manitudes are the same:

$$\frac{f}{f_0} = 10^{-m/2.5} \left[1 - b^2 \cdot 10^{2m/2.5} \right] \Big|_{b=0} = 10^{-m/2.5}$$

and

$$\begin{aligned} m &= \frac{-2.5}{\ln(10)} \left[\sinh^{-1} \left(\frac{f}{2bf_0} \right) + \ln(b) \right] \Big|_{b=0} = \\ & \frac{-2.5}{\ln(10)} \left[\ln \left(\frac{f}{2bf_0} + \sqrt{1 + \frac{f^2}{4b^2 f_0^2}} \right) + \ln(b) \right] \Big|_{b=0} = \\ & \frac{-2.5}{\ln(10)} \left[\ln \left(\frac{f}{2f_0} + \sqrt{b^2 + \frac{f^2}{4f_0^2}} \right) \right] \Big|_{b=0} = \\ & \frac{-2.5}{\ln(10)} \left[\ln \left(\frac{f}{f_0} \right) \right] = \\ & -2.5 \log \left(\frac{f}{f_0} \right) \end{aligned}$$

Although, as it can be seen in the previous calculation, the use in code of the general asinh formula for both Pogson (b=0) and asinh (b>0) magnitudes is not recommended, as it could easily produce numerical infinities during the evaluation.

References

- [1] Girardi et al (2002) **Theoretical isochrones in several photometric systems**, A&A 391,195- 212
- [2] Straizys V. (1996) **The method of Synthetic Photometry**, Baltic Astronomy, V5, 459-476
- [3] O'Connell, **Magnitude and Color Systems**, ASTR 511/O'Connell Lec 14
- [4] Bruijne (2003) **Stellar fluxes: transformations and calibrations**, ESA Tech. Note
- [5] Bessell, M.S. (2005) **Standard Photometric Systems**, Ann.Rev.Astron.Astrophys, 43:293-336
- [6] Longo G., **Notes on photometric systems zero-points**, IVOA internal report (2008)
- [7] Maiz, J. (2007) **A Uniform Set of Optical/NIR Photometric Zero Points to be Used with CHORIZOS**, ASP Conference Series, V999
- [8] Oke J.B., Wade R.A., A (1982) **Spectrophotometric Survey of Cataclysmic Variable Stars**, The Astrophysical Journal, V87, N4, 670-679

[9] **Lupton, Robert H.; Gunn, James E.; Szalay, Alexander S. (1999) A Modified Magnitude System that Produces Well-Behaved Magnitudes, Colors, and Errors Even for Low Signal-to-Noise Ratio Measurements**, The Astrophysical Journal, V118, Issue 3, pp. 1406-1410