Spectral quantities in use for Planetary Science

Notes based on doc PR-SpectralDM-2.0-20160928 and UCD v1.3

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Particularities of Planetary Science measurements & data include:

- measurements are usually performed in reflected light, sometimes in emission. Quantities of interest are often radiance / corresponding black body (either the Sun or the target itself)
- targets are often resolved spatially, which requires the use of local coordinate systems and the description of the illumination /viewing geometry
- coordinate systems related to the target body. Variations exist for a given body (E or W longitudes, planetocentric / graphic, corotating or not, etc)
- measurements can be localized in 3D (either depth or altitude)
- measurements of physical samples (either in the lab or in situ)
- …

Spectral types of measurements

Solar System measurements of light are performed either in reflection (with Sun as a light source) or in emission (usually in the mid-IR and above); some measurements can be provided in transmission (from occultations, etc).

Many spectral data related to observations of the Solar System are not calibrated / distributed in flux, but as different quantities adapted to resolved/extended sources:

- radiance: power radiated from the source, per unit area (in reflected light this depends on the light source spectrum and distance)
The radiance of a source can be derived from a measured flux but this has to be calibrated (depends whether the field of view is filled or not, and on observer-source distance), therefore no simple conversion can be performed on the fly.

- reflectance: generalization of "albedo", i. e., measured radiance relative to incoming power (intrinsic quantity, but depends on illumination geometry). Several variations exist depending on context/configuration (eg, lab vs observations, referenced to a Lambertian surface, etc)

Table 1 is a proposal for new quantities to support this field of studies, with description in the frame of SDM2. These UCDs are required to handle spectral data properly, i. e., using the correct scale.

An ambiguity in the UCD doc has to be clarified first: these quantities seem to belong to phys.*, because they describe intrinsic properties of the source. However, it seems that the phys domain now relates more and more exclusively to generic physical quantities (not related to sources), although there are many exceptions (phys.magAbs in particular). In this case, the phot domain is more appropriate (like phot.mag).

These quantities can be provided per unit wavelength (more frequent in the visible and IR) or per unit frequency, consistently with the spectral axis; the unit of power is usually W but can vary.

F is the "solar flux" and depends on Sun-source distance.

Except for radiance these quantities are dimensionless, but use different scales that must be identified in order to compare different data. They are proposed as sub strings of phys, but this may not be practical. Grouping them in phys.spectr. or phys.reflectance.something may be more clear.

Data.FluxAxis.Value **/ name**	**Data.FluxAxis.ucd**	**Data.FluxAxis.unit**	**Possible equivalent UCD**
Radiance (=I)	phot.radiance (exists in UCD 1.3, but see below)	W * m**(-2) * sr**(-1) * mu**(-1) (and variations)	phys.luminosity;phys.angArea;em.wl (heavy…)
Radiance factor (RADF) = r (commonly called "reflectance") (pb: this explicitly refers to reflected light, therefore relevant only at short wvl) = "**I/F ratio**" (I/F may include thermally emitted light)	phys.reflectance (would not cover emitted light) - OK in Feb 2018 phys.I_over_F? (would be more general) - postponed in 2018	dimensionless	phys.albedo;em.wl (but ambiguous, and only when emission is negligible). Equal to "normal albedo" at i=e=0° (and phase = 0°) only arith.ratio;phot.flux.density - not even sure because this is the ratio of a radiance to an integrated flux (hence dimensionless) Ratio of radiance to that of a Lambertian disk at the same distance and illuminated normally

Absorption coefficient	phys.absorption.coef - std		
Refraction index (including complex)	phys.refractIndex - std		

Derived quantities			
Bidirectional reflectance = r = I/F	~~phys.bidir?~~ phys.reflectance. bidirectional.df - accepted in Feb 2018, *we ird*	sr**(-1)	Ratio of radiance to incident normal solar flux
bidirectional reflectance distribution function (BRDF) = r / µ0	~~phys.brdf?~~ phys.reflectance. bidirectional.df - accepted in Feb 2018	sr**(-1)	(mostly used in terrestrial remote sensing)
Reflectance factor (REFF) = Radiance coefficient r/µ0	~~phys.reff?~~ phys.reflectance.factor - accepted in Feb 2018	dimensionless	Ratio of radiance to that of a Lambertian disk at the same distance and illuminated under the same incidence (used with laboratory samples)
Normalized reflectance	~~arith.ratio;phys.reflectance~~ ? no: arith.ratio is S M4ast currently uses (better, std) phys.reflectance;em.wl; arith.ratio would do: phys.reflectance;arith.ratio	dimensionless	Normalized to 1 at some wavelength
+ thermal / emission quantities	phys.emissivity Same as I/F for spectral measurements		I/F also apply to observations in the thermal range. What about lab measurements? + Apparent emissivity, etc…
+ Hemispherical quantities	Integrated in half space		TBC

Table 1: Quantities in use (µ0 stands for cosine of incidence angle; acronyms in parenthesis are from Hapke 1981 and are commonly used)

• About the current UCD 1.3 list:

phot.radiance was proposed in v 1.3 but may be inconsistent in the general case: it reflects an intrinsic property of the source (not a measured flux). It does depend on Sun-source distance for Solar System objects in reflectance, but not in the thermal range - therefore phys.radiance may be more adapted, TBC.

Other quantities are intrinsic and belong to phys, as indicated above (like luminosity, magAbs, albedo, and polarization).

phys.albedo is OK but not very specific; variations may have to be included (e.g., normal albedo if the target is resolved, Bond albedo, etc + depends on wvl). Same applies to phys.emissivity

Other quantities

The above quantities are intended to be used in the spectral data model, and used by VO tools to handle data properly.

They would also be available as values of the measurement_type parameter in EPN-TAP

• Since reflectance and radiance are functions of illuminated conditions, describing the illumination angles is also required.

Currently, only the phase angle has a defined UCD (pos.phaseAng). This is also required for incidence and emergence; azimuth can be useful also (the 4 angles are related):

pos.incidenceAng (adopted)

pos.emergenceAng (adopted)

~~pos.azimuthAng~~ (refused for questionable reasons but OK… pos.azimuth was adopted instead)

• bodycentric/graphic systems

Standard names are planetocentric/graphic - but this may apply also to the Sun, TBC.

Planetocentric latitude refers to the equatorial plane and the polar axis of the body
Planetographic latitude is defined as the angle between equatorial plane and a vector through the point of interest that is normal to the biaxial ellipsoid reference surface of the body
Planetocentric longitude is measured eastwards (i.e. positive in the sense of rotation) from the prime meridian. Planetographic longitude of the sub-observation point increases with time, i.e. to the west for prograde rotators and to the east for retrograde rotators (note: + for small bodies, N pole is defined so that bodies are prograde, as per IAU 2000 convention).

• We also have a demand to explicitely distinguish simulations from observations (and possibly experiments), which could go in the UCD

phys.reflectance;meta.modelled

It woud make sense to have similar UCDs for observed and experimental (ie: mesuared in the lab) quantities. Proposition

meta.observed

meta.experimental

• In addition:

We need an UCD to identify the date of last update in a dataset.

time.processing (existing) does not really relate to this

time.update would do.