Meteor Astrometry and Photometry Data Exchange Standard

Version 1.08, 31st March 2021

1. Purpose of this document

To define a standard format for exchange of astrometric and photometric data between fireball or meteor camera systems. The data relates to the capture by a single meteor camera of a single meteor path. It is intended to include all trajectory data in a single data file, including for multiple fragments and for different positional measurements.

2. Overview

The data consists of:

- The "Metadata", a description of the camera system including its exact location; and
- The "Point Observation Data", which is the direction, time and magnitude of each point of the meteor's observed path. This is stored as a series of columns in comma-separated-value (CSV) format, where each row corresponds to a point in time.

An example of data in the Standard format is in Appendix 1. Exact definitions of the Metadata are in Appendix 2, and exact definitions of the Point Observation Data are in Appendix 3.

This standard was formulated after analysis of the internal data formats of seven meteor camera systems and one database interface format, and a draft paper describes that analysis. Please check that you have the latest version of this standard, available (with all related papers and documents) at https://github.com/UKFAll/standard.

3. Writing data files in Standard format

These items should be given standardised variable names then should be written in the format shown in Appendix 1, which is Astropy "Table" format. Much camera system software is not written in Python, in which case the first thirteen lines of the data file can be written as a single string and the individual data items will need to be written individually.

It is not expected that a "Standard" file should be written for every meteor captured by a camera, so it is up to the architect of each camera system to decide what constitutes a fireball and when data should be written in Standard format.

4. Reading data in Standard format

When reading, there should be toleration of:

- Absence of non-essential data;
- Presence of unexpected or extraneous data;
- Non-standard Metadata order; and/or
- Non-standard column order.

This tolerance is already part of Astropy Table parsing routines, if Python is used.

5. Naming of data files

When writing a data file in Standard form, please pay attention to its name. Use of standardised naming helps the recipient to organise data from multiple sources. The standardised naming follows this format:

2021-04-07T03_56_41_UFO_EastBarnet.ecsv, i.e.

YYYY-MM-DDTHH_MM_SS_SOFTWARE_Station.ecsv

Where:

- The date and time are UTC, rather than local time. UTC must always be used.
- Dash (-) and underscore (_) and T are used to break up the date and time to make it easier for a human to read.
- SOFTWARE is the meteor camera system and refers to the originating software, not the hardware or network – examples are DFN, FRIPON, RMS, ALLSKYCAMS, UFO, METREC, CAMS. If you are incorporating this standard into a new system, please choose a new abbreviation and update this standard to reflect your choice.

6. Appendices

1. Example of the standard format
2. Metadata definitions
3. Point Observation Data definitions
4. Describing meteoroid fragmentation, and/or centroid vs. velocity position picking

Appendix 1 - Example of the standard format

Please note that a group of test files is at https://github.com/UKFAll/standard, so that you can test your input routines.


```
# %ECSV 0.9
# ---
# datatype:
# - {name: datetime, datatype: string}
# - {name: ra, unit: deg, datatype: float64}
# - {name: dec, unit: deg, datatype: float64}
# - {name: azimuth, unit: deg, datatype: float64}
# - {name: altitude, unit: deg, datatype: float64}
# - {name: mag, datatype: float64}
# - {name: x_image, datatype: float64}
# - {name: y_image, datatype: float64}
# delimiter: ','
# meta: !!omap
# - {obs_latitude: 51.637402}
# - {obs_longitude: -0.1692}
# - {obs_elevation: 86.0}
# - {origin: UFOAnalyzer_Ver_224}
# - {location: EastBarnet}
# - {telescope: NW}
# - {camera_id: EastBarnet_NW}
# - {observer: H.H. Nininger }
# - {comment: This meteor was also seen from the same location by both a DFN and a GMN camera}
# - {instrument: Watec_902H2_Ultimate}
# - {lens: Tamron_GL412IRDD}
# - {cx: 720}
# - {cy: 576}
# - {photometric_band: GAIA G}
# - {image_file: M20210407_035641_EastBarnet_NW.AVI}
# - {isodate_start_obs: '2021-04-07T03:56:40.250'}
# - {isodate_calib: '2021-04-07T03:56:42.590'}
# - {exposure_time: 4.68}
# - {astrometry_number_stars: 26}
# - {mag_label: mag}
# - {no_frags: 1}
# - {obs_az: 298.953644}
# - {obs_ev: 31.447386}
# - {obs_rot: -2.832725}
# - {fov_horiz: 64.745132}
# - {fov_vert: 51.796231}
# schema: astropy-2.0
datetime,ra,dec,azimuth,altitude,mag,x_image,y_image
2021-04-07T03:56:41.510,166.8385898,21.8464019,282.2609209,18.2187545,0.16,0.0,0.0
2021-04-07T03:56:41.570,166.6336298,21.5993546,282.2433474,17.9072948,0.11,0.0,0.0
2021-04-07T03:56:41.590,166.5622027,21.5164877,282.2396071,17.8011475,-0.04,0.0,0.0
2021-04-07T03:56:41.610,166.4962397,21.4343797,282.2324171,17.6988598,-0.34,0.0,0.0
2021-04-07T03:56:41.630,166.4189309,21.3532347,282.2343855,17.5904053,-0.48,0.0,0.0
2021-04-07T03:56:41.650,166.3782081,21.2773652,282.212872,17.508097,-0.64,0.0,0.0
2021-04-07T03:56:41.670,166.3161715,21.2064861,282.2106446,17.4166493,-0.52,0.0,0.0
2021-04-07T03:56:41.690,166.2403007,21.118417,282.207063,17.3037306,-0.53,0.0,0.0
2021-04-07T03:56:41.710,166.1863254,21.0420929,282.1952818,17.2129824,-0.78,0.0,0.0
2021-04-07T03:56:41.730,166.1158059,20.9758007,282.2026761,17.1198237,-0.9,0.0,0.0
```

Appendix 2 - Metadata definitions

Mandatory data items are shown in **bold**.

Variable Name	*Meaning*	*Format*
obs_latitude	**Decimal signed latitude (-90 S to +90 N)**	**Floating point, at least six decimals required**
obs_longitude	**Decimal signed longitude (-180 W to +180 E)**	**Floating point, at least six decimals required**
obs_elevation	**Altitude in metres above MSL. Note not WGS84, as only MSL is easily read from a handheld GPS unit.**	**Floating point or integer**
origin	The software which produced the data file, or from which the file was produced by a converter.	Free text, no quotation marks
location	The name of the city or location, which may have multiple cameras	Free text, no quotation marks
telescope	The identifier of the particular camera within the observatory – e.g. NW or 2	Free text, no quotation marks
camera_id	The code name of the camera, likely to be network-specific, e.g. ENGL01.	Free text, no quotation marks
observer	A person associated with the camera	Free text, no quotation marks
comment	Any text that could be useful to the recipient of the data. Should not contain the characters { or }	Free text, no quotation marks
instrument	The commercial camera model forming the basis of the camera system	Free text, no quotation marks
lens	The brand name and description of the camera lens	Free text, no quotation marks
cx	Horizontal camera resolution in pixels	Integer
cy	Vertical camera resolution in pixels	Integer
photometric_band	The photometric band of the star catalogue used for photometry calibration (e.g. V, R, GAIA G). It may also be a synthetic band, in which case the ratios should be listed (e.g. CAMS uses 0.1B + 0.4V + 0.4R + 0.1I).	Free text, no quotation marks
image_file	The name of the original image or video	Free text, no quotation marks
isodate_start_obs	The date and time of the start of the video or exposure, which will usually be a date and time occurring before the meteor is first detected	ISO 8601, at least 3 decimals, single quotation marks – see also Note A below
isodate_calib	The date and time corresponding to the astrometric calibration	ISO 8601, at least 3 decimals, single quotation marks – see also Note A below

Variable Name	***Meaning***	***Format***
exposure_time	The length of the video in seconds or the image exposure time in seconds	Floating, at least 2 decimals
astrometry_number_ stars	The number of stars identified and used in the astrometric calibration	Integer
mag_label	The label of the Magnitude column in the Point Observation data. "mag" is Astronomical Magnitude as produced by RMS and UFO, "FLUX_AUTO" is Flux within a Kron-like elliptical aperture as calculated by FRIPON.	Free text, no quotation marks
no_frags	The number of meteoroid fragments described in this data. If omitted, no_frags is assumed to be 1. See also Appendix 4, below.	Integer
obs_az	The azimuth of the centre of the field of view in decimal degrees. North = 0, increasing to the East	Floating, at least 3 decimals
obs_ev	The elevation of the centre of the field of view in decimal degrees. Horizon =0, Zenith = 90	Floating, at least 3 decimals
obs_rot	Rotation of the field of view from horizontal, decimal degrees. Clockwise is positive	Floating, at least 3 decimals
fov_horiz	Horizontal extent of the field of view, decimal degrees	Floating, at least 3 decimals
fov_vert	Vertical extent of the field of view, decimal degrees	Floating, at least 3 decimals

Note A: please always write dates according to the ISO 8601 standard, and in particular the form:

YYYY-MM-DDThh:mm:ss.sss

Please do not use ‘ ‘ instead of ‘T’ or vary this format in any other way. Also, UTC must always be used, so there is no scope in the standard to use any local or non-UTC timezone.

Appendix 3 - Point Observation Data definitions

A row of data is recorded for each point observation (i.e. for each half-frame of interlaced video, full frame of non-interlaced video, or shutter cycle for a shuttered non-video camera). Data is comma-separated.

Mandatory data items are shown in **bold**. RA and Dec are the position descriptors which are closest to raw data and so are mandatory in the Standard format. As the astrometry calibration is done by comparing stars on the image to stars in a catalogue, the equatorial coordinates should remain constant even with an offset in time[1]. The light curve should be calculated and recorded in some fashion as well (see below) to assist with both timing calibration and trajectory calculations.

Point Observation Data - date, time and positional data

Variable Name	*Meaning*	*Format*
datetime	**The date and time corresponding to the point observation**	**ISO 8601, at least 3 decimals, no quotation marks – see also Note A above**
ra	**The J2000 Right Ascension of the point observation, in decimal degrees**	**Floating point, at least six decimals required**
dec	**The J2000 Declination of the point observation, in decimal degrees**	**Floating point, at least six decimals required**
azimuth	**The calculated true azimuth of the point in epoch of date, expressed in decimal degrees. North = 0, increasing to the East. Please see Note 1 below.**	**Floating point, at least six decimals required**
altitude	**The calculated true elevation of the point in epoch of date, expressed in view in decimal degrees. Horizon =0, Zenith = 90. Please see Note 1 below.**	**Floating point, at least six decimals required**
x_image	The horizontal position of the point in the image (measured from the left), measured in pixels	Floating point
y_image	The vertical position of the point in the image (measured from the top), measured in pixels	Floating point
err_minus_altitude	Please see Note 2 below	Floating point
err_plus_altitude	Please see Note 2 below	Floating point
err_minus_azimuth	Please see Note 2 below	Floating point
err_plus_azimuth	Please see Note 2 below	Floating point

[1] Query – I am not sure that I understand this statement.

Note 1: Azimuth and Altitude are topocentric horizontal coordinates without any refraction correction (as they are projected on the sky, and not as apparent to the observer). To convert the reference equatorial coordinates in the J2000 epoch to these horizontal coordinates, RA and Dec need to be adjusted for precession to the epoch of date (that date being 'isodate_calib' as recorded in the Metadata), and converted to horizontal coordinates without any correction for refraction.

Note 2: For the azimuth and altitude, please calculate the one-standard-deviation positive/negative uncertainty corresponding to each angle and express it as decimal degrees. If your system doesn't explicitly calculate uncertainties, then please use a proxy that you believe is representative of the data quality from your system, for example the angular equivalent of 0.25 pixels (an average precision that can be achieved by centroiding).

Point Observation Data – recording the light curve

Variable Name	***Meaning***	***Format***
mag or FLUX_AUTO or no_mag_data or similar	The light curve – either the astronomical magnitude of the point (see Note 3 below) or any other related measure, as identified by the metadata item called "mag_label"	Floating point
saturated_pixels	Whether you think this particular observation is light-saturated, to help the recipient decide whether to ignore this frame.	True or False
integrated_pixel_value	[The sum of the pixel values across the whole frame]	Integer
err_minus_mag	Please see Note 4 below	Floating point
err_plus_ mag	Please see Note 4 below	Floating point

Note 3: If 'mag' is recorded, this should be the apparent magnitude in the given photometric band. As the data is for a single-station meteor observation, the distance or range of the meteor is unknown and so no attempt should be made to record a range-corrected "absolute" magnitude in this data.

Note 4: For your magnitude measurement, please calculate the one-standard-deviation positive/negative uncertainty corresponding to that calculation.

Appendix 4 - Describing meteoroid fragmentation, and/or centroid vs. velocity position picking

The mandatory columns of Point Observation Data are the **ra, dec, azimuth,** and **altitude** corresponding to a given point in time, as set out in Appendix 3. For most fireball observations there will be no complexity, but this standard accommodates the tracking of multiple fragments or the use of specialised velocity measurement as follows:

Fragmentation

If multiple fragments are described, then additional columns will be needed. The individual fragments are numbered from zero to no_frags-1 where 'no_frags' is the number of fragments recorded as in Appendix 2.

The fragment number is included in the column header. For example, columns corresponding to fragment 2 will be headed **ra2, dec2, azimuth2, altitude2, etc**. The only exception is fragment zero for which adding '0' to the column header is optional (so columns called **ra, dec, azimuth,** and **altitude** are identical in meaning to columns called **ra0, dec0, azimuth0,** and **altitude0** and either set of names may be used). As this is the only context in which numerals are used in column headers, it is easy to determine which fragment a column describes.

Centroid vs. Velocity position picking

Usually the Point Observation Data will be the best estimate of the position of the centre of each fragment, but occasionally a different point will be chosen, for example the leading edge of the fragment, in order to get a more accurate velocity measurement.

If a column corresponds to a velocity measurement then the upper-case character '**V**' is to be included in the column header. For example, columns corresponding to velocity measurement of fragment 2 will be headed **ra2V, dec2V, azimuth2V, altitude2V, etc**. As noted above, the corresponding centroid measurements, if included in the data file, will be headed **ra2, dec2, azimuth2, altitude2, etc**. As this is the only context in which the uppercase character 'V' is used in column headers, it is easy to determine which sort of position measurement a column describes.