# A Concise Description of the

# Astrometry Data Exchange Standard

Version 15-Jan-2018

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# 1 Introduction

This document describes the IAU Astrometry Data Exchange Standard (ADES) for small solar system objects, i.e., asteroids, comets, and natural satellites. ADES provides exchange formats and an associated data description that will facilitate transmission and storage of astrometric data, as generated by the observers, stored by the MPC, and processed by the orbit computers. Subsequent extensions to the standard may provide data structures to handle other data products, e.g., orbits and ephemerides.

ADES was formally adopted by IAU Commission 20 (Positions and Motions of Minor Planets, Comets and Satellites) at the IAU General Assembly held in Hawaii, USA in August 2015. The background, motivation, objectives and rationale of ADES are outlined in a preliminary description of the standard (published on MPEC 2015-O06 and available for download from the MPC[†]) and will not be repeated here. The ADES description here benefits from fine-tuning during the code development process and supersedes the preliminary description from 2015.

The ADES standard defines certain data types, which are detailed lists of information that either can or must be included in data submission, storage and exchange. These lists can be thought of either as records, such as the ones in a database, or as object classes, user defined data types, and so on. However, the standard defines the information content, not how these structures are implemented in computer codes handling the data.

[†] http://minorplanetcenter.net/iau/info/IAU2015_ADES.pdf

# 2 Overview

The MPC already has a longstanding standard format, referred to as MPC1992, and a message protocol for receiving astrometry, and it uses the same format to redistribute the data to users. After adoption of ADES, the MPC will continue to accept data in the MPC1992 format for the foreseeable future, although at some point the MPC1992 format will be judged obsolescent.

ADES includes two interchangeable file formats intended to meet the needs of the diverse small body astrometry community, including both producers and users of the data. The two formats are

- **XML** (eXtensible Markup Language) — This tag-based format allows for automated, schema-based validation of data and is in several ways more suited for large-scale data production and processing. However, XML is not a convenient form for manual editing and viewing of data files in conventional text editors.

- **PSV** (Pipe-Separated Values) — This format is a plain-text, pipe-delimited file (the pipe symbol is "|"), with one data record per line. The files can be produced so that the individual data fields are aligned from record to record, making it a convenient format for manual editing or inspection of data through a text editor.

In terms of content, the XML and PSV formats are fully equivalent and (with one exception) there are no losses of information in the process of transforming back and forth between the formats. (The exception to lossless translation being XML information stored in the `localUse` element described below, which is lost in translation to PSV.) MPC1992 data can readily be translated into ADES, but many ADES data fields cannot be represented in MPC1992, and so there may be information loss in translating from ADES to MPC1992.

# 3 Revising ADES

The formal process for revising ADES is not very formal. The MPC manages ADES revisions based on internal needs and in response to requests from the observing and orbit-fitting communities. Minor changes that do not necessarily impact existing ADES-compliant software can be implemented by the MPC after providing notice to the community, e.g., through an MPEC Editorial Notice. Major changes that have a substantive impact on existing software and work flows should be proposed to the community at large and to the Organizing Committee of IAU Commission X.2 (Solar System Ephemerides). The IAU may provide a suitable forum for discussion and feedback to the MPC on the proposed ADES revisions.

The versioning system for ADES identifies a version by the year in which it was adopted. While frequent version updates are not anticipated, if more than one version update is adopted in a given year the new version will have a lower-case letter appended, e.g., the second and third versions in 2017 would be 2017a and 2017b, respectively.

# 4 ADES in XML

This section describes the XML version of ADES. We first describe the overall, high-level structure of the ADES elements, and then turn to a detailed element-by-element description of the low-level ADES components. The PSV version of ADES will be described in Sec. 5, below.

Notes:

- In the following descriptions of the ADES XML structure, the ordering of the elements is explicit and must be maintained. This is an essential element for schema-based validation of the various data types in the ADES design.
- The capitalization scheme for ADES element names uses the so-called lowerCamelCase, i.e., lowercase except that wordbreaks are marked by an uppercase letter, e.g., '`radarResidual`'. Initialisms and acronyms (e.g., ID, RA, SNR) are not written in mixed case, e.g., `rmsRA`.
- Leading and trailing blanks in an element are ignored.
- The character encoding is specified by the XML preamble, but UTF-8 encoding is recommended as best practice for ADES files.

## 4.1 High-level ADES Structure

A valid ADES XML file uses XML version 1.0 and starts with an XML preamble. An ADES file must always include the ADES root element `ades` with a version attribute:

```
<?xml version='1.0' encoding='utf-8'?>
<ades version='2016'>
      ---ADES data here---
</ades>
```

At a high level, ADES allows for exchange of observations, observation context and observation residuals. There are four fundamental observation types, identified by the self-explanatory tags, `optical`, `offset`, `occultation` and `radar`. These observations can be packaged in different ways, depending upon the use case. The `ades` element itself can contain any of seven distinct elements, and these can appear in any number and in any order. Table 1 lists the elements that can appear in an `ades` element, and identifies where in this document additional information for these elements can be found.

**Table 1. Description of the ades root element. It can contain an unbounded list of any of the optional elements in any order. The obsBlock element is optional but at least one such element must be present in a valid MPC submission. The elements marked "N/S" are optional but must not be present in an MPC submission.**

ades Root Element

| Element | Use | Notes |
|---|---|---|
| obsBlock | OPT | See Table 2. Mandatory for MPC submissions. |
| optical | N/S | See Table 3 for description. |
| offset | N/S | See Table 3 for description. |
| occultation | N/S | See Table 3 for description. |
| radar | N/S | See Table 3 for description. |
| opticalResidual | N/S | See Table 13 for description. |
| radarResidual | N/S | See Table 14 for description. |

Of particular importance is the obsBlock element, which is the only ades element that is permitted in a submission to the MPC. As indicated in Table 2, an obsBlock contains one obsContext and one obsData element, in that order. The obsContext (Table 12) conveys what was once called the header information for MPC1992 submissions, and the obsData element can contain only a single type of observational data, either optical, offset, occultation or radar.

**Table 2. Description of the obsBlock subelements and their required order. The designation "REQ" indicates a required subelement.**

obsBlock Element

| Subelements | Use | Description |
|---|---|---|
| obsContext | REQ | See Table 12 for description. |
| obsData | REQ | An unbounded list of a single observation type, either optical, offset, occultation or radar. |

Thus, an ADES document could include all of the observations for a given object, with all of the optical, offset, occultation and radar elements appearing as immediate children of ades. Alternatively, for an MPC submission, ades could hold one or more obsBlock elements. Or, as another example, ades could hold a mix of opticalResidual or radarResidual elements.

We turn now to a description of the other elements that can appear in ades. In the next section (Sec. 4.2) we cover the observation elements (optical, offset, occultation and radar) and in Sec. 4.3 we describe obsContext and in Sec. 4.4 the residual elements (opticalResidual and radarResidual). Finally, in Sec. 4.5 we give the meaning and restrictions on the low-level elements.

## 4.2 Structure of ADES Observation Elements

With that explanation of the high-level structure of ADES, we can turn now to the structure and definition of the four observation elements. Table 3 displays the allowed subelements of the four observation elements. Here as elsewhere, the ordering of the elements must be as specified in the table. There are some sets of elements that, for convenience of description and presentation, are collected into groups in Table 3 and described in separate tables. It is emphasized that these groups are not hierarchical elements with child elements, but are simply groupings of related elements at the same hierarchical level as other elements in Table 3.

**Table 3. Observation element and their required order. The designation "REQ" indicates a required element, "OPT" denotes optional elements, "N/S" indicates elements that are generally optional but not permitted in MPC submissions. Forbidden elements are marked with "–". Groups of elements described separately are indicated by italic font in the first column, and their elements are tabulated and described below.**

| **Element** or ***Group*** | **optical** | **offset** | **occultation** | **radar** |
|---|---|---|---|---|
| *Identification Group* | REQ | REQ | REQ | REQ |
| obsID | N/S | N/S | N/S | N/S |
| trkID | N/S | N/S | N/S | – |
| mode | REQ | REQ | – | – |
| stn | REQ | REQ | REQ | – |
| trx | – | – | – | REQ |
| rcv | – | – | – | REQ |
| *Location Group* | OPT | OPT | OPT | – |
| prog | N/S | N/S | N/S | N/S |
| obsTime | REQ | REQ | REQ | REQ |
| *Observation Group* | REQ | REQ | REQ | REQ |
| astCat | REQ | – | REQ | – |
| *Photometry Group* | OPT | OPT | OPT | – |
| logSNR | OPT | OPT | OPT | OPT |
| seeing | OPT | OPT | OPT | – |
| exp | OPT | OPT | – | – |
| rmsFit | OPT | OPT | – | – |
| nStars | OPT | OPT | – | – |
| com | – | – | – | OPT |
| frq | – | – | – | REQ |
| ref | N/S | N/S | N/S | N/S |
| disc | OPT | OPT | OPT | – |
| subFrm | N/S | N/S | N/S | – |
| subFmt | N/S | N/S | N/S | – |
| *Precision Group* | N/S | N/S | N/S | – |
| uncTime | OPT | OPT | OPT | – |
| notes | OPT | OPT | OPT | – |
| remarks | OPT | OPT | OPT | OPT |
| *Optical Residuals Group* | N/S | N/S | N/S | – |
| *Radar Residuals Group* | – | – | – | N/S |
| deprecated | N/S | N/S | N/S | – |
| localUse | N/S | N/S | N/S | N/S |

### 4.2.1 Identification Group

The *Identification Group* (Table 4) includes four elements that are used to identify the object associated with the observation. As shown in Table 4, there are four alternate presentations (labeled A-D) for these elements. At least one of the elements is always required to be present, and, unless it is the only element present, `trkSub` is always optional. However, `radar` observations must always include at least one of `permID`, `provID` or `artSat`, and so Alternative D is not permitted for radar. If `artSat` is present then neither `permID` nor `provID` can be present, otherwise either or both `permID` and `provID` can be present.

**Table 4 Identification Group has four available fields that can be present in four alternate combinations as tabulated here and described in the text. Any alternative A-D can be used for `optical`, `occultation` or `offset` observations. Only alternatives A-C can be used for `radar` observations. The designation "`REQ`" indicates a required element, "`OPT`" denotes optional elements and "`–`" indicates that the field is forbidden.**

**Identification Group**

| | Alternatives | | | |
|---|---|---|---|---|
| **Element** | **A** | **B** | **C** | **D*** |
| permID | REQ | – | – | – |
| provID | OPT | REQ | – | – |
| artSat | – | – | REQ | – |
| trkSub | OPT | OPT | OPT | REQ |

* Alternative D not permitted for `radar` observations

The use of the Identification Group elements depends on the designation status of the target and the purpose behind the exchange of data. For unlinked submissions to the MPC, Alternative D in Table 4 applies, and `trkSub` must provide a user-assigned temporary designation, unique within the submission, for each tracklet in the submission. For targeted follow-up or recovery observations the user is encouraged to report the current designation of the target in either the `permID` or `provID` field, as the case may be. For a numbered object, `provID` should not be filled and may be ignored by the MPC. For targeted follow up with more than one tracklet of the same object in the submission, the `trkSub` field should be used to distinguish the individual tracklets. If the detection refers to a known artificial satellite then Alternative C must be used to convey the presumed identity of the target. The MPC has special processes and policies for submission and distribution of artificial satellite astrometry.

The `permID` and `provID` elements indicate the permanent or provisional designation of the object, respectively. (The past use of an MPC "packed" designation has been dropped, primarily because it is generally less readable, and the sorting advantages of the packed format require preservation of leading blanks and zeros, which is not in accord with the ADES formatting guidelines.) The MPC maintains the defining descriptions of the formal IAU designations, which are generally but not always represented verbatim in ADES. For minor planets and comets, the `permID` and `provID` format follows the associated formal IAU designation very closely, with the exception of removing parentheses around the permanent designation of numbered minor planets and eschewing subscripting in provisional designations of minor planets or former minor planets. For natural satellites, the IAU designation is preserved except that in permanent designations arabic numerals are used instead of roman numerals and for permanent designations of satellites of minor planets the name of the central body is neglected. The representation of the IAU designation in the `permID` and `provID` elements is given by examples in Table 5.

**Table 5. Example usage for `provID` and `permID` for various types of designations. This table does not provide an exhaustive list of all possible variations. The MPC defines the form of designations in cooperation with the IAU.**

| Object Type | IAU Designation | permID | provID |
|---|---|---|---|
| Minor Planet | (1) | 1 | |
| Minor Planet | (134340) | 134340 | |
| Minor Planet | (1234567) | 1234567 | |
| Minor Planet | 2014 AA | | 2014 AA |
| Minor Planet | 2014 $AA_1$ | | 2014 AA1 |
| Minor Planet | 2014 $AA_{360}$ | | 2014 AA360 |
| Minor Planet | 2014 $AA_{12345}$ | | 2014 AA12345 |
| Minor Planet | 4007 P-L | | 4007 P-L |
| Minor Planet | 4658 T-3 | | 4568 T-3 |
| Comet | 3D | 3D | |
| Comet | 1234P | 1234P | |
| Comet | C/1999 K7 | | C/1999 K7 |
| Comet | P/1886 S1 | | P/1886 S1 |
| Comet | P/1998 $QP_{54}$ | | P/1998 QP54 |
| Comet | C/1997 $BA_6$ | | C/1997 BA6 |
| Comet | C/1931 AN | | C/1931 AN |
| Comet Fragment | 73P-C | 73P-C | |
| Comet Fragment | 73P-AC | 73P-AC | |
| Comet Fragment | P/1994 P1-B | | P/1994 P1-B |
| Comet Fragment | C/1996 J1-A | | C/1996 J1-A |
| Satellite | Jupiter XIII | Jupiter 13 | |
| Satellite | (45) Eugenia I | (45) 1 | |
| Satellite | S/2001 U 9 | | S/2001 U 9 |
| Satellite | S/2001 S 31 | | S/2001 S 31 |
| Satellite | S/2008 (41) 1 | | S/2008 (41) 1 |
| Satellite | S/2000 (1998 $WW_{31}$) 1 | | S/2000 (1998 WW31) 1 |

### 4.2.2 Location Group

The *Location Group* (Table 6) includes the elements that are used only for observatories that are not at a fixed position on the surface of the Earth, or do not have a specific MPC-assigned observatory code (`stn`). These are primarily the so-called "roving" observers (MPC observatory code 247) and space-based observatories. The Location Group must be present for such cases, but must not be present if `stn` is associated with a stationary MPC observatory code. The Location Group is not permitted for `radar` observations.

**Table 6 Location Group description. The designation "`REQ`" indicates a required element and "`OPT`" denotes optional elements. The Location Group is not permitted for `radar` observations.**

| Location Group | |
|---|---|
| **Element** | **optical/offset/occultation** |
| sys | REQ |
| ctr | REQ |
| pos1 | REQ |
| pos2 | REQ |
| pos3 | REQ |
| posCov11 | OPT |
| posCov12 | OPT |
| posCov13 | OPT |
| posCov22 | OPT |
| posCov23 | OPT |
| posCov33 | OPT |

### 4.2.3 Observation Group

The *Observation Group* encapsulates the astrometry and its associated uncertainty. The elements are presented in Table 7. For `optical` observations, the elements are straightforward, with `ra`, `dec` both being required and the associated uncertainties, `rmsRA` and `rmsDec`, being optional. The correlation of uncertainty between RA and DEC is provide by the optional field `rmsCorr`. The `offset` and `occultation` observations are both measured through a displacement from a reference point, `obsCenter` for `offset` and `raStar` and `decStar` for `occultation`. For both of these observation types, the displacement can be measured either as a ΔRA and ΔDEC (`deltaRA` and `deltaDec`) or as a distance and direction in position angle (`dist` and `pa`). These are the cartesian and polar coordinate forms of the displacement from the reference, and either approach is permitted. Finally, for `radar` observations, the allowed value is either `delay` or `doppler`, and not both, and the associated uncertainty is required. Thus, except for `radar`, the observational uncertainties are optional fields, including `rmsCorr`.

**Table 7 Observation Group description. The allowed elements for each observation type are tabulated in the order required. All element names that appear in parentheses are optional. Others are mandatory, except that a vertical bar indicates a choice, e.g., the offset and occultation observations could be reported in `deltaRA` and `deltaDec`, or alternatively in `dist` and `pa`. Similarly, radar observations can report either `doppler` or `delay`. The RMS element must, of course, align with that of the reported observable.**

**Observation Group**

| optical | offset | | occultation | | radar | |
|---|---|---|---|---|---|---|
| | | | raStar | | | |
| | obsCenter | | decStar | | | |
| ra | deltaRA | dist | deltaRA | dist | doppler | delay |
| dec | deltaDec | pa | deltaDec | pa | rmsDoppler | rmsDelay |
| (rmsRA) | (rmsRA) | (rmsDist) | (rmsRA) | (rmsDist) | | |
| (rmsDec) | (rmsDec) | (rmsPA) | (rmsDec) | (rmsPA) | | |
| (rmsCorr) | (rmsCorr) | | (rmsCorr) | | | |

### 4.2.4 Photometry Group

Photometric observations are a part of the optional Photometry Group, as depicted in Table 8. While the entire group is optional, if photometry is to be included with an observation then the required elements in the group must be present.

Observers should note that the photometric `band` to report is the same as that of the reference star magnitudes used to calibrate the exposure. It is not necessarily the same as the filter through which the exposure was taken. In particular, unfiltered exposures should never be reported with a band of 'none' or 'clear'. If the color of the target is known, then it may be possible to apply a color term correction to a chosen bandpass, if the proper transformation is known, in which case the band to report should correspond to the result of the transformation.

**Table 8 Photometry Group description. The designation "`REQ`" indicates a required element and "`OPT`" denotes optional elements. The Photometry Group is not permitted for `radar` observations.**

**Photometry Group**

| Element | optical/offset/occultation |
|---|---|
| mag | REQ |
| rmsMag | OPT |
| band | REQ |
| photCat | OPT |
| photAp | OPT |
| nucMag | N/S |

### 4.2.5 Precision Group

For observations that were translated from MPC1992 or earlier formats, the Precision Group preserves the precision of the original reported observation and allows the content of the original sexagesimal submission to be derived. The elements in the Precision Group are tabulated in Table 9, where one can see that, though the entire group is optional (but not allowed in MPC submissions), if any precision information is present then all three elements in the group must be present.

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**Table 9 Precision Group description. The designation "REQ" indicates a required element. While the precision group is optional (and not for submission), if any of the group's elements are present then all must be present. The Precision Group is not permitted for `radar` observations.**

| Precision Group | |
|---|---|
| **Element** | **optical/offset/occultation** |
| precTime | REQ |
| precRA | REQ |
| precDec | REQ |

### 4.2.6 Residuals Groups

Table 3 indicates that there are two groups related to the exchange of observational residuals, the *Optical Residuals Group* (Table 10) and the *Radar Residuals Group* (Table 11). These groups are optional for the observations to which they apply, but are not permitted in MPC submissions. Thus, a radar observation may contain radar residuals (and the other observation types may include optical residuals) but not for MPC submission. Each of these two residual groups start with an identification element for the orbit producer (`orbProd`) and then the orbital solution, (`orbID`), both required.

For the *Radar Residuals Group*, the next elements are the residual value, selection flag and measurement uncertainty, with the element names conforming to the type of measurement used in the observations, either delay or Doppler.

The *Optical Residuals Group* has the extra feature that, following the required ID block, it may include either an *Astrometry Subgroup* or a *Photometry Subgroup*, or both, in that order. Within one of these blocks there are some required items (residuals, selection flags, and sigmas) and the rest are optional. Thus, at a minimum, the *Optical Residuals Group* must contain the elements [`orbProd`, `orbID`], and either [`resRA`, `resDec`, `selAst`, `sigRA`, `sigDec`] or [`photProd`, `resMag`, `selPhot`, `sigMag`] (or both).

Table 10 Optical Residuals Group description. The designation "REQ" indicates a required element, "OPT" denotes optional elements. Either the Astrometry or Photometry subgroup, or both, must be present. The Optical Residuals Group is not permitted for radar observations.

**Optical Residuals Group**

| Element | | optical/offset/occultation |
|---|---|---|
| orbProd | ID | REQ |
| orbID | | REQ |
| resRA | Astrometry Subgroup | REQ |
| resDec | | REQ |
| selAst | | REQ |
| sigRA | | REQ |
| sigDec | | REQ |
| sigCorr | | OPT |
| sigTime | | OPT |
| biasRA | | OPT |
| biasDec | | OPT |
| biasTime | | OPT |
| photProd | Photometry Subgroup | OPT |
| resMag | | REQ |
| selPhot | | REQ |
| sigMag | | REQ |
| biasMag | | OPT |
| photMod | | OPT |

Table 11 Radar Residuals Group description. The designation "REQ" indicates a required element, "OPT" denotes optional elements. The vertical bar indicates a choice, e.g., the residual information can be reported either in doppler or delay, depending on the type of radar observation reported. The Radar Residuals Group is not permitted for optical, offset or occultation observations.

**Radar Residuals Group**

| Element | | radar |
|---|---|---|
| orbProd | | REQ |
| orbID | | REQ |
| resDelay | resDoppler | REQ |
| selDelay | selDoppler | REQ |
| sigDelay | sigDoppler | REQ |

## 4.3 Observation Context

Following the discussion of the ADES observation elements, we now turn to describe the other high-level ADES elements, starting with obsContext, which is a required subelement of obsBlock. The obsContext serves the purpose of what was called the header information in MPC1992 submissions. It is metadata that provides useful context for the associated observations in obsData. As shown in

Table 12, most of the components of obsContext have child subelements that contain the actual information, the exception being fundingSource, which has no children. In several cases, as marked with an asterisk in Table 12, the name or line subelement can appear repeatedly, with a minimum of one occurrence. An example of the obsContext element is presented in Sec. 4.6.

**Table 12. Elements of obsContext and their required order. In every case except one (fundingSource), the tabulated subelements of obsContext have child elements that convey the relevant information. The designation "REQ" indicates a required element or subelement, and "OPT" denotes optional. For subelements marked with an asterisk "REQ(*)", an unbounded list of the subelement must be present, with a minimum of one occurrence.**

**obsContext Element**

| Element | Use | Subelements | Use |
|---|---|---|---|
| observatory | REQ | | |
| | | mpcCode | REQ |
| | | name | OPT |
| submitter | REQ | | |
| | | name | REQ |
| | | institution | OPT |
| observers | REQ | | |
| | | name | REQ(*) |
| measurers | REQ | | |
| | | name | REQ(*) |
| telescope | REQ | | |
| | | name | OPT |
| | | design | REQ |
| | | aperture | REQ |
| | | detector | REQ |
| | | fRatio | OPT |
| | | filter | OPT |
| | | arraySize | OPT |
| | | pixelScale | OPT |
| software | OPT | | |
| | | astrometry | OPT |
| | | fitOrder | OPT |
| | | photometry | OPT |
| | | objectDetection | OPT |
| coinvestigators | OPT | | |
| | | name | REQ(*) |
| collaborators | OPT | | |
| | | name | REQ(*) |
| fundingSource | OPT | *—None—* | |
| comment | OPT | | |
| | | line | REQ(*) |

## 4.4 Residual Elements

The last high-level ADES elements to be discussed are the `opticalResidual` (Table 13) and `radarResidual` (Table 14) elements, which allow exchange of residual information without including the associated observational information. As described above, residuals may be included within an observation as detailed in the discussion of the *Residuals Groups* in Sec. 4.2.6. However, residuals information can also appear as an immediate child of an `ades` element by including information that allows each of the residuals to be referred to its associated observations. Thus, the `opticalResidual` and `radarResidual` elements start with the *Identification Group* (Sec. 4.2.1) as well as the `obsID` and `trkID` (if available) and `obsTime` from the associated observation. These elements allow the subsequent *Optical Residuals Group* (Table 10) or *Radar Residuals Group* (Table 11) to be unambiguously linked to the associated observation element, which is presumably stored separately.

**Table 13. The subelements of the `opticalResiduals` element in their required order. The designation "`REQ`" indicates a required element, and "`OPT`" denotes optional elements.**

**`opticalResidual` Element**

| **Element or *Group*** | **Use** | **Notes** |
|---|---|---|
| *Identification Group* | REQ | See Table 4. Must agree with associated observation. |
| obsID | OPT | Should be included if available. |
| trkID | OPT | Should be included if available. |
| obsTime | REQ | Must agree with associated observation. |
| *Optical Residuals Group* | REQ | See Table 10 for description. |

**Table 14. The subelements of the `radarResiduals` element in their required order. The designation "`REQ`" indicates a required element, and "`OPT`" denotes optional elements.**

**`radarResidual` Element**

| **Element or *Group*** | **Use** | **Notes** |
|---|---|---|
| *Identification Group* | REQ | See Table 4. Must agree with associated observation. |
| obsID | OPT | Should be included if available. |
| obsTime | REQ | Must agree with associated observation. |
| *Radar Residuals Group* | REQ | See Table 11 for description. |

## 4.5 ADES Low-level Elements

This section tabulates the low-level elements that are a part of the various modes of observation (Table 16), part of the residuals information (Table 17) or part of the observation context (Table 18).

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The number of digits in the provided measurements should be consistent with the stated or assumed uncertainty. Reported uncertainties should be reported with two significant figures if the leading significant digit is '1', otherwise either one or two significant figures is appropriate when reporting uncertainty. Submissions with more than two significant figures in reported uncertainties may be rejected by the MPC.

The observations themselves should be reported with at least one but never more than two significant figures (i.e., a factor ~10-100) beyond the measurement accuracy. Thus, observations reported in degrees that have accuracies in the range 0.036-0.36 arcsec would reasonably be reported with six significant figures past the decimal point. Similarly, photometry with magnitude uncertainties in the range 0.1-1.0 may be reasonably reported to the nearest 0.01 mag. Figure 1 provides guidance on how many digits should be reported after the decimal point for ADES angular and photometric observations. The plots are generated with the formula

```
DP = CEILING(1 - LOG10(SIGMA)),
```

where `DP` is the number of digits after the decimal point, `SIGMA` is the reported uncertainty and `CEILING` is a function that rounds up to the next greater integer value. The MPC may reject observations reported with a gratuitous number of digits.

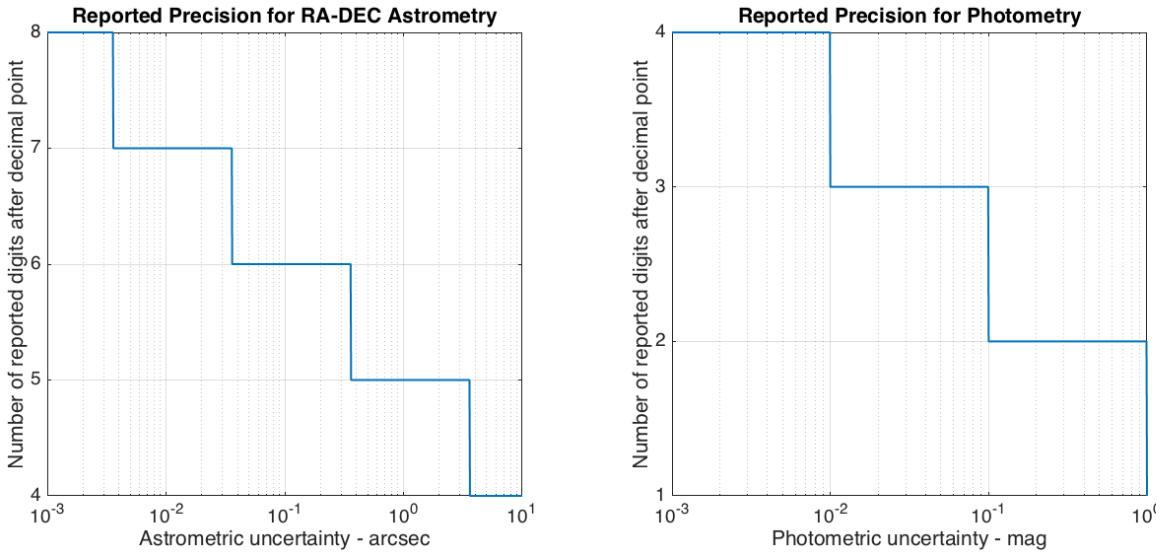


**Figure 1. Suggested numerical precision in ADES observations for RA-DEC astrometry (left) and photometry (right) as a function of the measurement uncertainty.**

For other fields, besides measurements and uncertainties, the reported precision will depend on the circumstances. Table 15 provides recommended printing formats in both `FORTRAN` and `printf` styles as an aid to standardization.

**Table 15. Recommended output print specifications for selected ADES fields. These values are intended as an aid to standardization and it is understood that exceptional cases may require different specifications.**

| Element | FORTRAN | printf |
|---|---|---|
| rmsCorr | F6.3 | %6.3f |
| photAp | F4.1 | %4.1f |
| logSNR | F4.2 | %4.2f |
| seeing | F3.1 | %3.1f |
| rmsFit | F4.2 | %4.2f |

In the following tables, the term "String" allows any printable character in the XML character encoding, except for the pipe character "|", which is forbidden in any ADES element value to ensure compatibility with PSV. "Alphanumeric" describes the subset of String characters including the 52 upper and lower case ASCII letters, the ten ASCII numerals and the underscore character "_".

Several of the elements described below must match an approved list of values that is provided and maintained by the MPC. These include the following:

- Instrumentation type: `mode`
- Observatory designations, with location where appropriate: `stn`, `trx`, `rcv`
- Star catalogs: `astCat`, `photCat`
- Photometric passband: `band`
- Observing notes and meaning: `notes`
- Photometric model used for photometry residuals: `photMod`

In the case of photMod, the MPC list is not restrictive, but is intended to aid standardization

**Table 16. Observation elements and their descriptions. Elements associated with a grouping as discussed in Sec. 4.2 and Table 3 are highlighted by gray shading.**

| Element | Description | Restrictions |
|---|---|---|
| *Identification Group Elements:* | | |
| permID | IAU permanent designation, e.g., the IAU number for a numbered minor planet. See discussion at Sec. 4.2.1. | See Table 5 for examples. |
| provID | MPC provisional designation (in unpacked form) for unnumbered objects. See discussion at Sec. 4.2.1. | See Table 5 for examples. |
| artSat | Artificial satellite identifier. | String. |
| trkSub | Observer-assigned tracklet identifier, unique within a submission batch. Not altered by the MPC. This will typically be the same as the observer-assigned temporary designation previously employed for the MPC1992 format. This element can be used to distinguish individual tracklets among observations of the same object within a submission. This element can also be used by an observatory to facilitate tracebacks from MPC distributions to observer submissions. See discussion at Sec. 4.2.1. | Up to 8 alphanumeric characters. |
| obsID | Globally unique observation identifier assigned by the MPC. For observers, this field can be used to communicate a correction to a previously published observation. | Up to 19 alphanumeric characters. |
| trkID | Globally unique tracklet identifier assigned by the MPC. | Up to 12 alphanumeric characters. |
| mode | Mode of instrumentation. | Up to 3 alphanumeric characters. Full list of acceptable field names to be provided and maintained by the MPC. Key examples follow: |

| mode | Description |
|---|---|
| **PHO** | Photographic |
| **ENC** | Encoder |
| **CCD** | CCD |
| **MER** | Meridian or transit circle |
| **MIC** | Micrometer |
| **NOR** | Normal place |
| **VID** | Mini-normal place from video frames |
| **PMT** | Photo-multiplier tube |

| | | |
|---|---|---|
| `stn` | Observatory code assigned by the MPC. This could be a ground-based station with published coordinates or a roving or space-based station with coordinates given by the Location Group elements listed below. | Either 3 or 4 alphanumeric characters, typically one code per observatory. The old three-character codes will be preserved where practical, or a fourth character will be added, e.g., `568a`, `568b`, etc. The list of `stn` codes and associated locations to be provided and maintained by the MPC. |
| `trx`<br>`rcv` | Station codes of transmitting and receiving antenna. | Either 3 or 4 alphanumeric characters. The list of `trx` and `rcv` codes and associated locations to be provided and maintained by the MPC. |
| *Location Group Elements:* | | |
| `sys` | Coordinate frame for roving or space-based station coordinates. The five possible values and their interpretation are as follows:<br>For ground-based roving observers<br>• '`WGS84`' (geodetic reference ellipsoid, GPS coordinates are normally obtained in this frame)<br>• '`ITRF`' (cylindrical)<br>• '`IAU`' (IAU planetary cartographic model for bodies other than Earth)<br>For space-based observatories<br>• '`ICRF_AU`' (cartesian)<br>• '`ICRF_KM`' (cartesian) | A string with five possible values listed at left. |
| `ctr` | Origin of the reference system given by `sys`. Use public SPICE codes, e.g., 399 is geocenter, 10 is Sun center. (See http://naif.jpl.nasa.gov/pub/naif/toolkit_docs/C/req/naif_ids.html - NAIF Object ID numbers) | An integer. NOTE: `sys=WGS84` implies `ctr=399`. |

| | | |
|---|---|---|
| pos1<br>pos2<br>pos3 | Position of observer. Interpretation depends on the value of sys as follows:<br>• WGS84: East longitude (deg), latitude (deg), altitude(m)<br>• ITRF: East longitude (deg), $R_{xy}$ (km), $R_z$(km)<br>• IAU: longitude (deg), latitude (deg), altitude (m) as defined by corresponding IAU cartography standard (http://astrogeology.usgs.gov/groups/IAU-WGCCRE)<br>• ICRF_AU or ICRF_KM: Equatorial rectangular coordinates (au or km) in the IAU International Celestial Reference Frame. | Decimal number. The number of digits provided should be consistent with the uncertainty in the coordinates. |
| posCov11<br>posCov12<br>posCov13<br>posCov22<br>posCov23<br>posCov33 | Upper triangular part of (pos1, pos2, pos3) covariance matrix in same units of position coordinates (e.g., $km^2$ if sys = 'ICRF_KM'). Missing fields are presumed zero. | Decimal number. The number of digits provided should be consistent with the uncertainty in the coordinates. |
| prog | Program code assigned by the MPC, and used to identify different observing programs/observers at the same telescope. For surveys and other large producers, the MPC will increment prog for a given observatory code to document a significant operational change reported by the observing team. | Up to 2 alphanumeric characters. |
| obsTime | UTC date and time of the observation. For observations derived from optical telescope images this is typically the mid-exposure time of the image. Observations for which obsTime falls during a leap second are technically compliant with the ADES standard but are strongly discouraged. | ISO 8601 extended format, i.e., yyyy-mm-ddThh:mm:ss.sssZ. The reported time precision may be greater than shown in the example above, but should be appropriate for the astrometric accuracy. The trailing Z indicates UTC and is required. |
| *Observation Group Elements:* | | |
| ra<br>dec | For optical observations, the right ascension (RA) and declination (DEC) in decimal degrees in the J2000.0 reference frame. | Decimal number in the following ranges: 0 ≤ ra < 360, –90 ≤ dec ≤ +90. Positive DEC values may optionally include a '+'-sign. |
| raStar<br>decStar | For occultation observations, the RA and DEC in the J2000.0 reference frame in decimal degrees of the occulted star. | Decimal number in the following ranges: 0 ≤ ra < 360, –90 ≤ dec ≤ +90 |

| | | |
|---|---|---|
| obsCenter | Origin of offset observation. | The full name of a planet or Earth's Moon (e.g., 'Jupiter' or 'Moon'), or a permID, or a provID. |
| deltaRA<br>deltaDec | Measured ΔRA*cos(DEC) and ΔDEC in arcsec in the J2000.0 reference frame for offset measurements of a satellite with respect to obsCenter, or for occultation observations with respect to the star specified by raStar and decStar. | Decimal number. |
| dist<br>pa | Measured distance in arcsec and position angle (PA) in degrees in the J2000.0 reference frame for offset measurements of a satellite with respect to obsCenter, or for occultation observations with respect to the star specified by raStar and decStar. | Decimal number in the following ranges: dist ≥ 0, 0 ≤ pa < 360. |
| rmsRA<br>rmsDec | For ra–dec and deltaRA–deltaDec observations, the random component of the RA*COS(DEC) and DEC uncertainty (1σ) in arcsec as estimated by the observer as part of the image processing and astrometric reduction. | Positive decimal number. Presumed systematic errors, e.g., those arising from star catalog biases, should not be included in the uncertainties reported in this field. $rmsRA^2$ and $rmsDec^2$ are the diagonal elements of the RA-DEC covariance matrix, which convolves errors from target PSF fitting, telescope tracking, reference star fit, etc. |
| rmsDist<br>rmsPA | For dist–pa observations, the random component of the distance and PA uncertainty (1σ) in arcsec and degrees, respectively, as estimated by the observer as part of the image processing and astrometric reduction. | Positive decimal number. Presumed systematic errors, e.g., those arising from star catalog biases, should not be folded into the uncertainties reported in this field. $rmsDist^2$ and $rmsPA^2$ are the diagonal elements of the distance-PA covariance matrix, which convolves errors from target PSF fitting, telescope tracking, reference star fit, etc. |

| | | |
|---|---|---|
| `rmsCorr` | Correlation between RA and DEC or between distance and PA that may result from the astrometric reduction. It can be especially relevant for trailed images or cases with a poor distribution of reference stars. This is derived from the RA-DEC covariance matrix, where the off-diagonal term is `rmsCorr` × `rmsRA` × `rmsDec`. A similar prescription holds for `dist-pa` observations. | Decimal number in the range −1 ≤ `rmsCorr` ≤ +1. |
| `delay` | Observed radar time delay in s. | Positive decimal number. |
| `rmsDelay` | Delay uncertainty in μs.<br>NOTE: This uncertainty is not a strict one standard deviation error in a normal distribution, but is the "standard error of measurement", a discrete bound related to both systematic and random errors. | Positive decimal number. Note that the units of `delay` and `rmsDelay` are different. |
| `doppler` | Observed radar Doppler shift in Hz. | Decimal number. |
| `rmsDoppler` | Doppler shift uncertainty in Hz. See NOTE at `rmsDelay`. | Positive decimal number. |
| `astCat` | Star catalog used for the astrometric reduction or, in the case of `occultation` observations, for the occulted star. | Alphanumeric string up to 8 characters. Full list of acceptable values to be provided and maintained by the MPC. This field must be present, and so a specified value, e.g., 'UNK', will be used for some archival observations to indicate that the astrometric catalog is unknown. |
| *Photometry Group Elements:* | | |
| `mag` | Apparent magnitude in specified band. | Decimal number. |
| `rmsMag` | Apparent magnitude uncertainty (1σ) in magnitudes. | Positive decimal number. |
| `band` | Passband designation for photometry. | Alphanumeric string up to 3 characters. Full list of acceptable values to be provided and maintained by the MPC. |
| `photCat` | Star catalog used for the photometric reduction. | Alphanumeric string up to 8 characters. Full list of acceptable values to be provided and maintained by the MPC. |
| `photAp` | Photometric aperture radius in arcsec. | Positive decimal number. |

| | | |
|---|---|---|
| nucMag | Nuclear magnitude flag for comets. Primarily used for archival data as photAp should be used to communicate this information in the new standard. | Logical (Integer: 0=False and 1=True). True for archival cometary nuclear magnitude measurements. False otherwise, in which case the nucMag element should be neglected. |
| logSNR | The log10 of the signal-to-noise ratio of the source in the image integrated on the entire aperture used for the astrometric centroid. | Decimal number. |
| seeing | Size of seeing disc in arcsec, measured at Full-Width, Half-Max (FWHM) of target point spread function (PSF). | Positive decimal number. |
| exp | Exposure time in seconds. Total exposure time in the case of stacked image detections. | Positive decimal number. Except for very short exposures, this field should generally be printed as an integer with no decimal point. |
| rmsFit | RMS of fit of astrometric comparison stars in arcsec. | Positive decimal number. |
| nStars | Number of reference stars in astrometric fit. | Positive integer. |
| com | Flag to indicate that the observation is reduced to the center of mass. False implies a measurement to the peak power position, which is usually interpreted as the leading edge of the target, with the reflection point being modeled one object radius prior to the center of mass. | Logical (Integer 0=False and 1=True). Assumed True if not present. |
| frq | Carrier reference frequency in MHz. | Positive decimal number. |
| ref | Standard reference field used for citations. | String up to 16 characters. |
| disc | Discovery flag. A '*' marks a new discovery record and a '+' marks the first measurement of a previously observed object. Normally filled only by the MPC. | Two allowed values: '*' and '+'. |
| subFrm | Originally reported reference frame for angular measurements. This element defines the frame used in the reduction of the measurements and is intended primarily for archival observations. The subFrm element does not reflect the frame of the associated ADES observations, which are always J2000.0. | String with allowed values of the form 'APP.' for apparent or 'B*<four-digit year>*.0', e.g., B1950.0 will be a common value for archival data. The subFrm element is not permitted for new submissions, which must be reduced with respect to the J2000.0 frame. |

| | | |
|---|---|---|
| subFmt | Format in which the observation was originally submitted to the MPC. Filled by the MPC. | Up to four alphanumeric characters. Example values are listed in following table: |

| subFmt | Format |
|---|---|
| PRE | Pre-MPC |
| M47 | MPC1947 |
| M92 | MPC1992 |
| A17 | ADES v2017 |
| A18a | ADES 2018a |

| *Precision Group Elements:* | | |
|---|---|---|
| precTime | Precision in millionths of a day of the reported observation time for archival MPC1992 and earlier data. | Integer. Allowed values: 1, 10, 100, 1000, 10000, 100000. Printed as integer, with no decimal point. |
| precRA<br>precDec | Reported precision for archival MPC1992 or earlier data, in seconds for precRA and in arcsec for precDec. | Positive decimal number. Allowed values: 0.001, 0.01, 0.1, 1, 0.6, 6, 60. Integer values are printed as an integer, with no decimal point. Non-integer values printed with a leading zero and no trailing zeros, e.g., '0.1' and not '.10'. |
| uncTime | Estimated time uncertainty in seconds. Unlike the preceding RMS fields, which indicate random errors, this field indicates a presumed level of systematic clock error. NB: This field is generally only to be used to communicate exceptions and problems with clock calibration and is not intended to be used in routine submissions where clock errors are not a significant source of astrometric error. | Positive decimal number. |
| notes | A set of one-character note flags to communicate observing circumstances. | Alphanumeric string up to 6 characters in length. List of acceptable flags and their interpretation to be provided and maintained by the MPC. |
| remarks | A comment provided by the observer. This field can be used to report additional information that is not reportable in the notes field, but that may be of relevance for interpretation of the observations. Should be used sparingly by major producers. | String, up to 200 characters in length. |

| *See* Table 17 *for a description of elements related to the Optical and Radar Residuals Group, which might otherwise fall here in the order of description.* | | |
|---|---|---|
| `deprecated` | This field, if present, indicates a deprecated observation that is preserved for historical purposes, but is not to be used for orbit fitting. | 'X' is the only permitted value. |
| `localUse` | This element is intended as a container to hold subelements carrying ancillary information not envisioned by the standard. This element is not present in the ADES PSV format and so any `localUse` information will be lost in translation to PSV. | There are no restrictions on what can be included under localUse, but this element may not be present in a submission to the MPC. For instance, `localUse` may contain the CCD number of the detection in a mosaic, or the x-y location of the detection in the CCD, or polynomial coefficients used in the plate solution, etc. |

**Table 17. Residual subelements and their descriptions.**

| **Element** | **Description** | **Restrictions** |
|---|---|---|
| `orbProd` | Orbit producer. | String, with no standard format. Can be an institution, individual, or even email address. |
| `orbID` | Local reference for orbit. | String, with no standard format, e.g., 'JPL 7' or 'MPO 12345'. |
| `resRA`<br>`resDec` | Residuals in RA*COS(DEC) and DEC in arcsec. | Decimal number. |
| `selAst` | Selection (i.e., inclusion or rejection) flag for astrometry. | Valid values:<br>• 'A' or 'D' for automatic accept/delete<br>• 'a' or 'd' for forced accept/delete |
| `sigRA`<br>`sigDec` | Adopted RA*COS(DEC) and DEC uncertainties (1σ) in arcsec. | Positive decimal number. May be different from the observer provided uncertainties. [NOTE: The RA-Dec covariance reported here and in the related `sigCorr` element must not include uncertainty associated with time uncertainty as reported in the `sigTime` element.] |
| `sigCorr` | Adopted correlation between RA*COS(DEC) and DEC. | Decimal number between -1 and 1, inclusive. May be different from the observer provided correlation. Assumed zero if not present. |
| `sigTime` | Adopted time uncertainty (1σ) in seconds. | Positive decimal number. Assumed zero if not present, i.e., timing error not considered in orbital solution. |
| `biasRA`<br>`biasDec` | Adopted RA*COS(DEC) and DEC biases in arcsec. | Decimal number. Assumed zero if not present. A bias is subtracted from the reported value to obtain the corrected value. |
| `biasTime` | Adopted time bias in seconds. | Decimal number. Assumed zero if not present. |

<table>
<tr><td>photProd</td><td>Producer of photometric residuals.</td><td>String, with no standard format. Can be institution, individual's name, email address, etc. If not present then the value given for orbProd is presumed.</td></tr>
<tr><td>resMag</td><td>Photometric residual in magnitudes.</td><td>Decimal number.</td></tr>
<tr><td>selPhot</td><td>Selection flag for photometry.</td><td>Valid values:<ul><li>'A' or 'D' for automatic accept/delete</li><li>'a' or 'd' for forced accept/delete</li></ul></td></tr>
<tr><td>sigMag</td><td>Adopted magnitude uncertainty (1σ) in magnitudes.</td><td>Positive decimal number. Could be different from the observer provided uncertainty.</td></tr>
<tr><td>biasMag</td><td>Adopted photometric bias in magnitudes.</td><td>Decimal number. Assumed zero if not present. A bias is subtracted from the reported value to obtain the corrected value.</td></tr>
<tr><td>photMod</td><td>Description of the photometric model used in obtaining the photometric residuals.</td><td>Up to 8 alphanumeric characters without a required standard format. Some standard values are given in the following table.<table><tr><th>photMod</th><th>Description</th></tr><tr><td>H</td><td>H-G system with G=0.15</td></tr><tr><td>HG</td><td>H-G with different value of G</td></tr><tr><td>HG1G2</td><td>H-G1-G2 system</td></tr><tr><td>HG12</td><td>H-G12 system</td></tr><tr><td>NEATM</td><td>NEA Thermal Model</td></tr><tr><td>FRM</td><td>Fast Rotator Model</td></tr></table>Additional standard values for this element will be established by the MPC in consultation with the small body research community.</td></tr>
<tr><td>resDelay<br>resDoppler</td><td>Residual of the radar measurement in μs for delay, Hz for Doppler.</td><td>Decimal number.</td></tr>
<tr><td>selDelay<br>selDoppler</td><td>Selection flag for radar astrometry.</td><td>Valid values:<ul><li>'A' or 'D' for automatic accept/delete</li><li>'a' or 'd' for manual accept/delete</li></ul></td></tr>
<tr><td>sigDelay<br>sigDoppler</td><td>Adopted uncertainty for the radar measurement in μs for delay, Hz for Doppler.</td><td>Positive decimal number.</td></tr>
</table>

Table 18. Observation context elements and their children.

| Element | Child Elements | Description | Restrictions |
|---|---|---|---|
| observatory | mpcCode | MPC assigned observatory code (of receiver for radar) | 3 or 4 char. alphanumeric |
| | name | Observatory name | String |
| submitter | name | Name of individual submitting data to MPC | String |
| | institution | Affiliation of submitter | String |
| observers | name | Names of observers (initials then surname), one individual per name element. | String |
| measurers | name | Names of measurers (initials then surname), one individual per name element. | String |
| telescope | name | Name of observatory or telescope | String |
| | design | Telescope design, e.g., reflector, Schmidt, Schmidt-Cassegrain | String |
| | aperture | Telescope aperture in meters | Pos. decimal |
| | detector | Type of detector, e.g., 'CCD' | String |
| | fRatio | Telescope f-number, the ratio of telescope focal length to aperture | Pos. decimal |
| | filter | Description of telescope filter(s) | String |
| | arraySize | Array size (X×Y), after binning, of the individual detector chip. | String |
| | pixelScale | Angular extent of pixel in arcseconds (geometric mean of x & y extents for non-square pixels). | Pos. decimal |
| software | astrometry | Description of software used for astrometry | String |
| | fitOrder | Order of fit for astrometric solution | String |
| | photometry | Description of photometry software, if different from astrometry software. | String |
| | objectDetection | Description of software for object detection, if different from astrometry or photometry software. | String |
| coinvestigators | name | Names of coinvestigators (initials then surname), one individual per name element. | String |
| collaborators | name | Names of collaborators (initials then surname), one individual per name element. | String |
| fundingSource | | Description of source of funding. | String |
| comment | line | Explanatory remarks. Multiple line elements can be included and order is to be preserved. | String |

## 4.6 An ADES example in XML

The following example demonstrates a correct ADES file that includes a single `obsBlock` with a single `optical` observation.

```
<?xml version='1.0' encoding='UTF-8'?>
<ades version="2017">
  <obsBlock>
    <obsContext>
      <observatory>
        <mpcCode>568</mpcCode>
        <name>Univ. Hawaii</name>
      </observatory>
      <submitter>
        <name>I. M. Submit</name>
      </submitter>
      <observers>
        <name>I. M. Observit</name>
        <name>A. N. Astronomer</name>
      </observers>
      <measurers>
        <name>I. M. Measurit</name>
        <name>A. N. Skywatcher</name>
      </measurers>
      <telescope>
        <design>reflector</design>
        <aperture>2.2</aperture>
        <detector>CCD</detector>
      </telescope>
      <fundingSource>Name of Funding Agency</fundingSource>
      <comment>
        <line>This is the first comment.</line>
        <line>This is the second comment.</line>
      </comment>
    </obsContext>
    <obsData>
      <optical>
        <permID>1234567</permID>
        <provID>2018 AA1234</provID>
        <trkSub>a1b2c3d4</trkSub>
        <mode>CCD</mode>
        <stn>568a</stn>
        <prog>31</prog>
        <obsTime>2016-08-29T12:32:34.12Z</obsTime>
        <ra>215.6560501</ra>
        <dec>-13.5478723</dec>
        <rmsRA>0.015</rmsRA>
        <rmsDec>0.013</rmsDec>
        <rmsCorr>-0.215</rmsCorr>
        <astCat>2MASS</astCat>
        <mag>21.91</mag>
        <rmsMag>0.25</rmsMag>
        <band>w</band>
        <photCat>PPMXL</photCat>
        <photAp>13.3</photAp>
        <logSNR>0.78</logSNR>
        <seeing>0.8</seeing>
        <exp>1200</exp>
        <notes>klmnp</notes>
        <remarks>High winds affected tracking</remarks>
      </optical>
    </obsData>
  </obsBlock>
</ades>
```

# 5 ADES in PSV

The PSV form of an ADES document preserves the structure of the XML document. While there is a different approach to formatting the ADES context and observational information, the translation between the two presentations preserves all information. To guide the description of the PSV format, the following example depicts the PSV translation of the XML example file given in Sec. 4.6, above.

```
# version=2017
# observatory
! mpcCode 568
! name Univ. Hawaii
# submitter
! name I. M. Submit
# observers
! name I. M. Observit
! name A. N. Astronomer
# measurers
! name I. M. Measurit
! name A. N. Skywatcher
# telescope
! design reflector
! aperture 2.2
! detector CCD
# fundingSource Name of Funding Agency
# comment
! line This is the first comment.
! line This is the second comment.
permID |provID     |trkSub   |mode|stn |prog|obsTime                 |...
1234567|2018 AA1234|a1b2c3d4| CCD|568a|  31|2016-08-29T12:32:34.12Z|...

(The following lines are broken only for display in this document. In the actual PSV file, the lines continue beyond the ellipses.)

ra          |dec         |rmsRA|rmsDec|rmsCorr|astCat  |mag  |rmsMag|band|...
215.6560501|-13.5478723|0.015|0.013 |-0.215 |   2MASS|21.91|0.25  |   w|...

photCat |photAp|logSNR|seeing|exp |notes|remarks
   PPMXL|13.3  |0.78  |0.8   |1200|klmnp|High winds affected tracking
```

The following rules guide the interpretation of PSV and its translation to and from XML.

- To avoid character mangling, PSV files must always be exchanged in the UTF-8 character encoding.
- The PSV file always begins with a "# version=" record that documents the ADES version used in generating the file.
- The XML `obsBlock` element always begins with an `obsContext` element that is represented in PSV by a series of *Context Records* starting with either a '**#**' character or a '**!**' character. A '**#**' followed by an element name (and possibly a value) indicates an item listed as an element of `obsContext` in Table 12. Similarly, a '**!**' character followed by an element name and value denotes a child element of the immediately preceding `obsContext` element.

- A new `obsBlock` is indicated by the first record from the associated `obsContext`, which must be "`# observatory`".
- The end of the `obsContext` and start of the `obsData` element is signaled by a *Keyword Record*, which is a pipe-separated listing of the names of the elements that appear in subsequent *Data Records*. A Keyword Record is identified as any record not starting with '`#`' or '`!`' for which all pipe-separated tokens (after stripping leading and trailing blanks) start with a lower-case letter [a-z].
- Data Records follow a Keyword Record, with one Data Record per observation. Like the Keyword Record, the element values on a DATA record are separated by pipe characters. If the data type changes, for instance from optical to radar, then a new Keyword Record can be written to describe the subsequent data. In the extreme case (outside of an `obsData` element), every Data Record could be preceded by its own specific Keyword Record.
- The end of an `obsData` element, and the enclosing `obsBlock` element is marked either by a second Keyword Record or a new series of `obsContext` records, which must always start with "`# observatory`". This immediately implies that all Data Records in an `obsData` element must associate to a single Keyword Record. Given that an `obsBlock` represents a homogeneous set of observations, this is not an obstacle.
- The Identification Group elements (Table 4) must be the first elements appearing on a Keyword Record. This assures that a Data Record is not mistaken as an `obsContext` record. Other elements can appear in any order, although a default template is described below.
- The type of observation in a Data Record can be unambiguously determined by the non-empty fields present, and so the tags `optical`, `radar`, etc. do not appear in PSV.
- Blanks will normally be used as padding to obtain column alignment of the data fields, but this is not strictly necessary. Null fields are empty (i.e., consecutive delimiters: '||') or filled with blanks in the blank-padded format.
- Since the pipe character '|' serves as delimiter it is not an allowed character in the fields defined by this standard.
- The `localUse` element in XML is neglected in PSV.
- In the absence of an associated `obsContext` element, Data Records are interpreted as immediate children of the `ades` root element. On the other hand, Data Records that follow the first Keyword Record after any Context Records are part of an `obsBlock`.

## 5.1 Default PSV Formatting

As a convenience for some users, the ADES standard does define an optional default PSV template. The objective of the default mode is to ensure column-wise alignment of the most commonly reviewed fields. This will allow key fields to be found in "familiar" locations and will ensure that records can be cut and pasted from different files and still be aligned. While this mode of output is not required by the

standard, it is specified by the standard so that users can have a means of ensuring that the key information from multiple files is column-aligned.

The default formatting applies primarily to `optical` observations, which comprise the bulk of the available astrometric data set. Table 19 lists the element names, their order and the field width for the default `optical` template. In some cases, e.g., `prog` and `rmsCorr`, the field widths in Table 19 are wider than the data in order to accomodate the width of the field name. Any fields present in the record but not listed in Table 19 will be placed in Table 16, order between the `notes` and `remarks` fields. With this format, the record length is 166 characters (plus any additional fields after the `notes` and any `remarks`).

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**Table 19. Field formatting for the default PSV template in ADES.**

| Default PSV Formatting | | |
|---|---|---|
| **Element** | **Width** | **Justification** |
| permID | 7 | R |
| provID | 11 | L |
| trkSub | 8 | R |
| mode | 4 | R |
| stn | 4 | L |
| prog | 4 | R |
| obsTime | 23 | L |
| ra | 11 | D4 |
| dec | 11 | D4 |
| rmsRA | 5 | D2 |
| rmsDec | 6 | D2 |
| rmsCorr | 7 | D3 |
| astCat | 8 | R |
| mag | 5 | D3 |
| rmsMag | 6 | D2 |
| Band | 4 | R |
| photCat | 8 | R |
| photAp | 6 | D3 |
| logSNR | 6 | D2 |
| seeing | 6 | D2 |
| exp | 4 | R |
| notes | 5 | L |
| remarks | Variable | L |

NOTES: The tabulated column width is a minimum and may be expanded if alignment with field names is requested. Justification is either right (R), left (L) or by placing the decimal point in a given column within the field (e.g., D3 makes the decimal point the 3rd character within the field).

For `offset` and `occultation` observations, the default template follows Table 19, except that the Observation Group elements are to appear in the order specified by Table 7 in place of the corresponding elements (`ra` and `dec`) shown in Table 19.

Thus, for example, `obsCenter`, `deltaRA`, and `deltaDec`, in that order, would replace `ra` and `dec` in Table 19 for an `offset` observation. Field widths and justification are not specified for the alternate Observation Group elements. For radar observations `delay`, `rmsDelay`, `doppler` and `rmsDoppler` appear, in that order, on every record in the default template, though two of these fields will always be blank. An additional `radar` exception is that the `mode` and `stn` elements in Table 19 are replaced by the `trx` and `rcv` elements, both with four-character width and left justification.

Conversion utilities will include the option to produce files with the default template. However, use of the default template is not required: the only requirement for submission is the compliance with the general standards detailed in this document.

# 6 Implementation Plan

After adoption by the MPC, ADES will become the MPC's primary means of data submission and dissemination, and observers are strongly encouraged to adopt the new format as soon as practicable. The 80-column MPC1992 format will be deprecated but will continue to be accepted for an indefinite but limited time period.

The submission of ADES observations to the MPC will be possible in three ways: Web form, cURL script, or email. The only acceptable format for email submission is anticipated to be XML, either compressed or uncompressed. For the observers who prefer the PSV format, an MPC web interface to upload observation submissions will be provided. The backend engine of the web interface will convert the supplied data file to XML and validate it as a part of the ingestion pipeline at the MPC. The MPC will also disseminate the data in the XML form of ADES, eventually with the option of downloading the observation residual data and observation context information. Users may use local scripts or MPC web forms to convert from XML to PSV and back.

## 6.1 ADES Software

To support the transition to the new format, some key ADES software tools will be made publicly available. The objective of this effort is to facilitate the development of software and libraries in a number of widely used languages, e.g., Perl, Python, C and FORTRAN. The software package will include ADES XML schema, I/O libraries for extending custom software, and file utilities for error checking, conversion, merging and splitting. The ADES software package will be distributed through a community-accessible portal, e.g., https://github.com/IAU-ADES or by the MPC.

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Table 9