IVOA Provenance Data Model
Version 1.0

IVOA Working Draft 2018-05-30

Working group
DM

This version
http://www.ivoa.net/documents/ProvenanceDM/20180530

Latest version
http://www.ivoa.net/documents/ProvenanceDM

Previous versions
WD-ProvenanceDM-1.0-20170921.pdf
WD-ProvenanceDM-1.0-20161121.pdf
ProvDM-0.2-20160428.pdf
ProvDM-0.1-20141008.pdf

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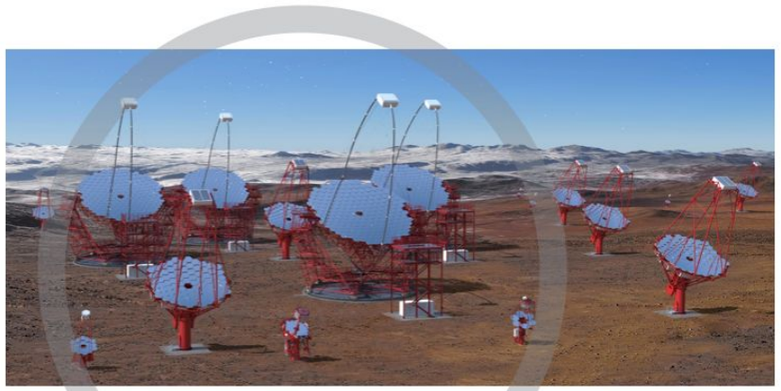
Objectives and context



Observatory

Consortium

Data acquisition
(triggers, cameras, …)

Data Centers
(data processing, reduction, reconstruction, simulations, …)

Additional data

End User

Archive, Dissemination

Web portal

Publications

- Data product generation **obscure** to end user
- **Quality**, **reliability**, **trustworthiness**?
- **Usefulness** of the data?

Need **structured** and **detailed** provenance information

Use cases

- CTA pipeline and data access
- RAVE (Radial Velocity Experiment)
- POLLUX (synthetic stellar spectra service)
- SVOM gamma ray burst / transients
- TAP-based API for images in an archive @CDS
- APPLAUSE database
- MUSE WISE pipeline

⇒ Different aspects of Provenance

- How to **collect** the provenance information
- How to **store** this information
- How to **access** and **visualize** the provenance

Draft content

1 Introduction

- 1.1 Goal of the provenance model
- 1.2 Minimum requirements for provenance
- 1.3 Role within the VO architecture
- 1.4 Previous efforts

2 The provenance data model

- 2.1 Overview: Conceptional UML class diagram and introduction to core classes
- 2.2 Model description
  - 2.2.1 Class diagram and VO-DML compatibility
  - 2.2.2 Entity (and EntityDescription)
  - 2.2.3 Collection
  - 2.2.4 Activity and ActivityDescription
  - 2.2.5 ActivityFlow
  - 2.2.6 Entity-Activity relations
  - 2.2.7 Parameters
  - 2.2.8 Agent

define sub-entities

separate section

link to ProvONE?

separate section

3 Serialization of the provenance data model

- 3.1 Introduction
- 3.2 Serialization formats: PROV-N, PROV-JSON and PROV-XML
- 3.3 PROV-VOTable format
- 3.4 Serialization of description classes for web services
- 3.5 W3C PROV-DM compatible serializations

comes with ProvTAP

can all IVOA concepts fit in W3C serializations?

4 Accessing provenance information

Appendix A Serialization Examples

Appendix B Links to other data models

- B.1 Links with Dataset/ObsCore Model
- B.2 Links with Simulation Data Model

Goals

A: Tracking the production history

Find out which steps were taken to produce a dataset and list the methods/tools/software that was involved.

B: Attribution and contact information

Find the people involved in the production of a dataset, that need to be cited or can be asked for more information.

C: Locate error sources

Find the location of possible error sources in the generation of a dataset.

D: Quality assessment

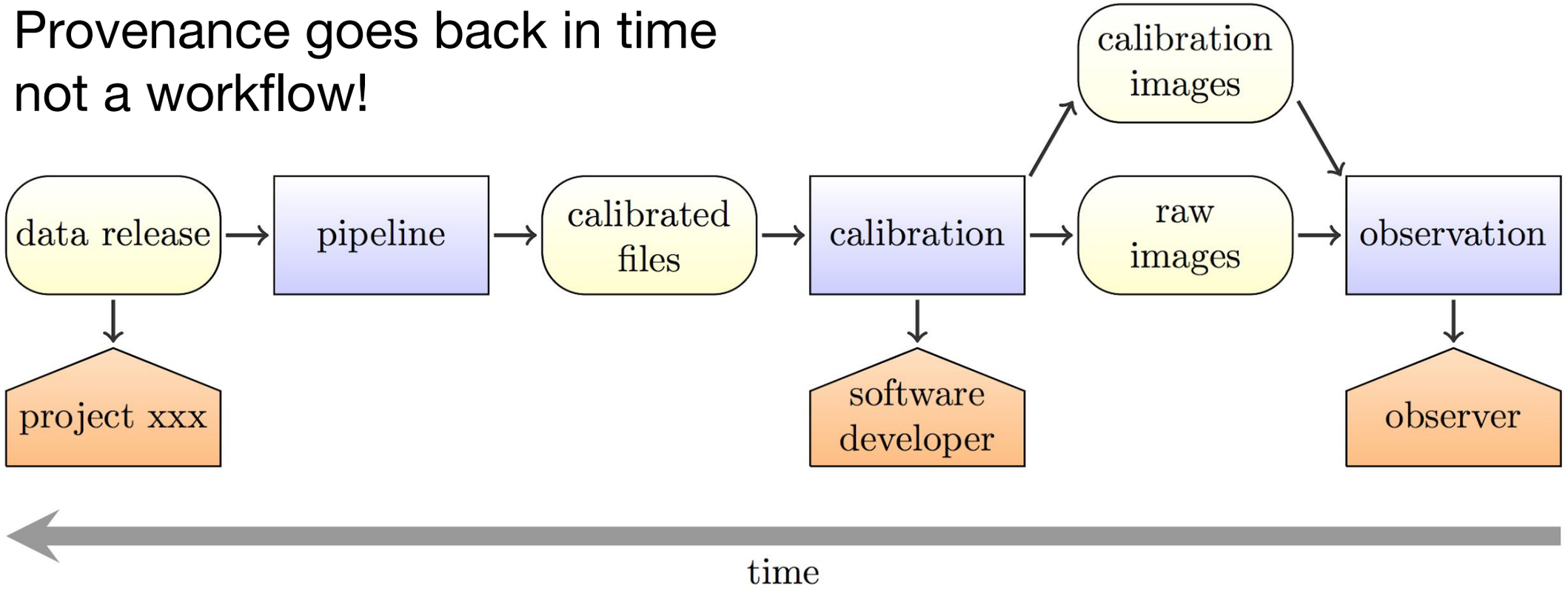
Judge the quality of an observation, production step or dataset.

E: Search in structured provenance metadata

This would allow one to also do a “forward search”, i.e. locate derived datasets or outputs.

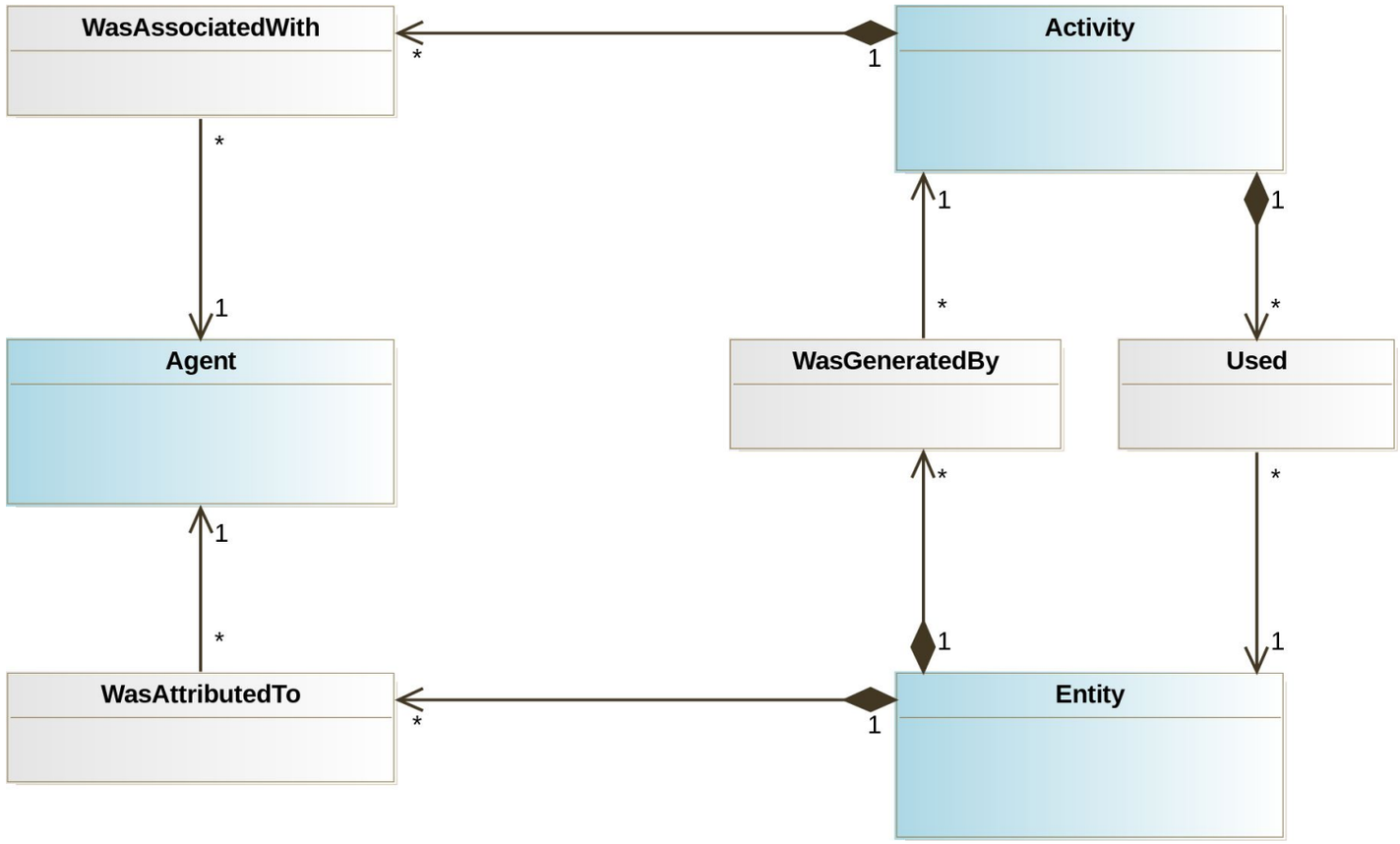
What is provenance?

Provenance goes back in time
not a workflow!



- **Provenance** = Identify how a data product was produced
- **Configuration** = Identify what detailed options were used
- **Contextual** information:
  - Instrument Configuration
  - Ambient Conditions
  - Software environment

Core Provenance Data Model



http://www.w3.org/TR/prov-overview/

30 April 2013

Word Wide Web Consortium

http://www.ivoa.net/documents/ProvenanceDM/

- Core concepts from the W3C PROV recommendations
  - **Entity - Activity - Agent**
  - **Relations** and **roles** = provenance information
  - W3C PROV has many more relations
  - IVOA Provenance connected to **VO concepts** and **astronomy needs**

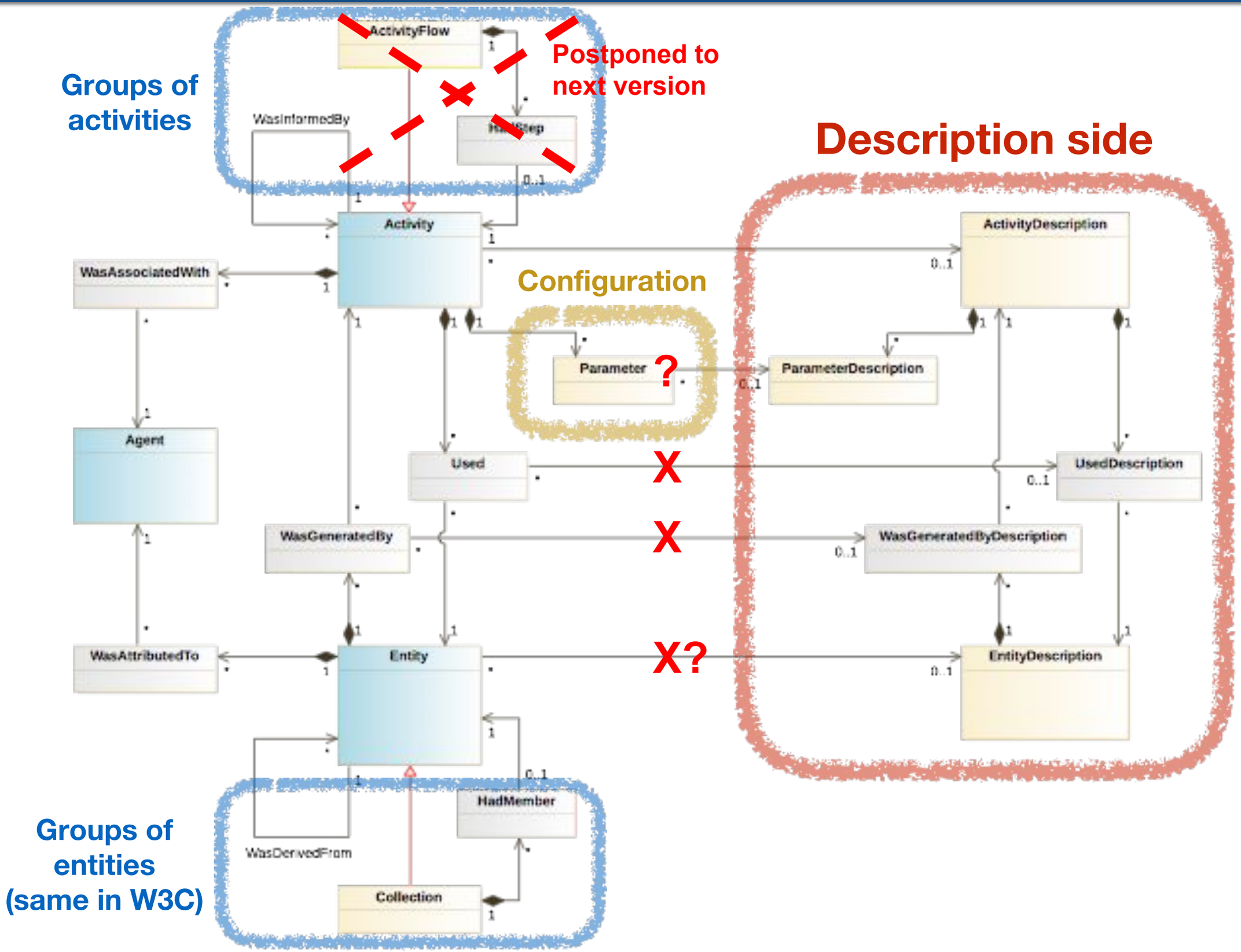
Concepts In Astronomy

- **Entities**: datasets composed of VOTables, FITS files or database tables, or files containing logs, values (spectra, lightcurves), parameters, etc.
- **Activities**: an observation, a simulation, or processing steps (image stacking, object extraction, etc.).
- **Agents**: the people involved can be individual persons (observer, publisher...), groups or organisations.
- **Connections to existing VO concepts**
  - Entity <—> Dataset (Curation, DataID), ObsCore, SimDM DataObject
  - Activity <—> SimDM (Resource, Experiment)
  - Agent <—> Party, Contact
- **Connections to external concepts** (PROV, ProvONE, DOI, ORCID, …)

Minimum requirements

1. Provenance information must be stored in a **standard model**, with **standard serialization formats**.
2. Provenance information must be **machine readable**.
3. Provenance data model classes and attributes should be **linked to other IVOA concepts** when relevant (DatasetDM, ObsCoreDM, SimDM, VOTable, UCDs...).
4. Provenance information should be **serializable into the W3C provenance standard formats** (PROV-N, PROV-XML, PROV-JSON) with minimum information loss.
5. Provenance metadata must contain information to find immediate **progenitor(s)** (if existing) for a given entity, i.e. a dataset.
6. An entity must point to **the activity that generated it** (if the activity is recorded).
7. Activities must point to **input entities** (if applicable).
8. Activities may point to **output entities**.
9. Provenance information should make it possible to derive the **chronological** sequence of activities.
10. Provenance information can only be given for **uniquely identifiable entities**, at least inside their domain.
11. Released entities should have a **main contact**.
12. It is recommended that all activities and entities have **contact information** and contain a (short) **description** or link to a description.

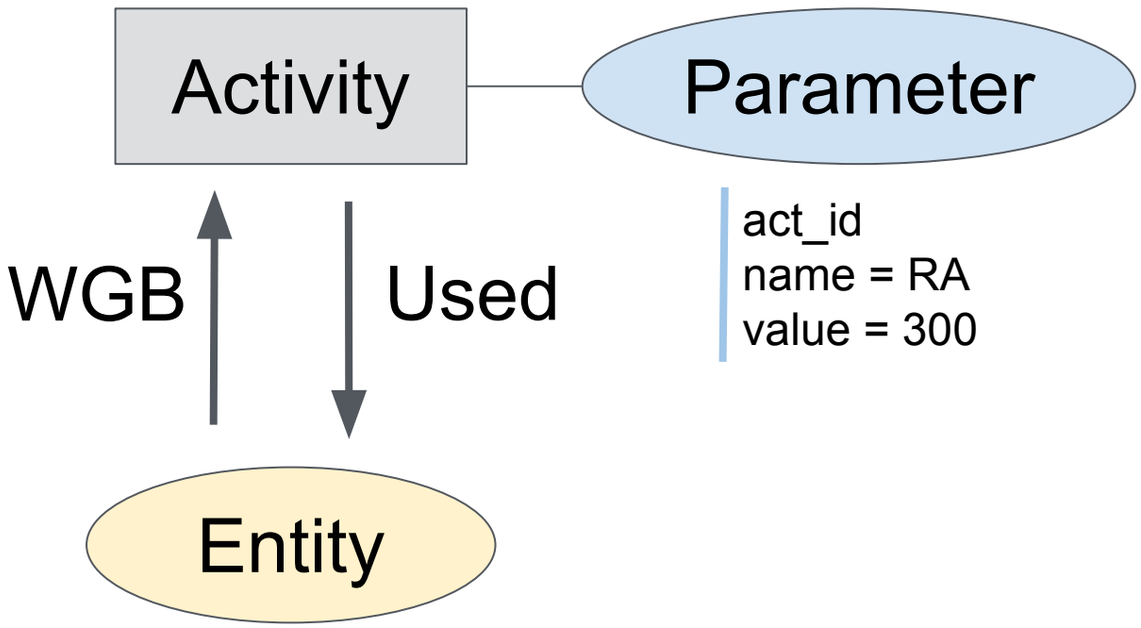
IVOA Provenance Data Model diagram



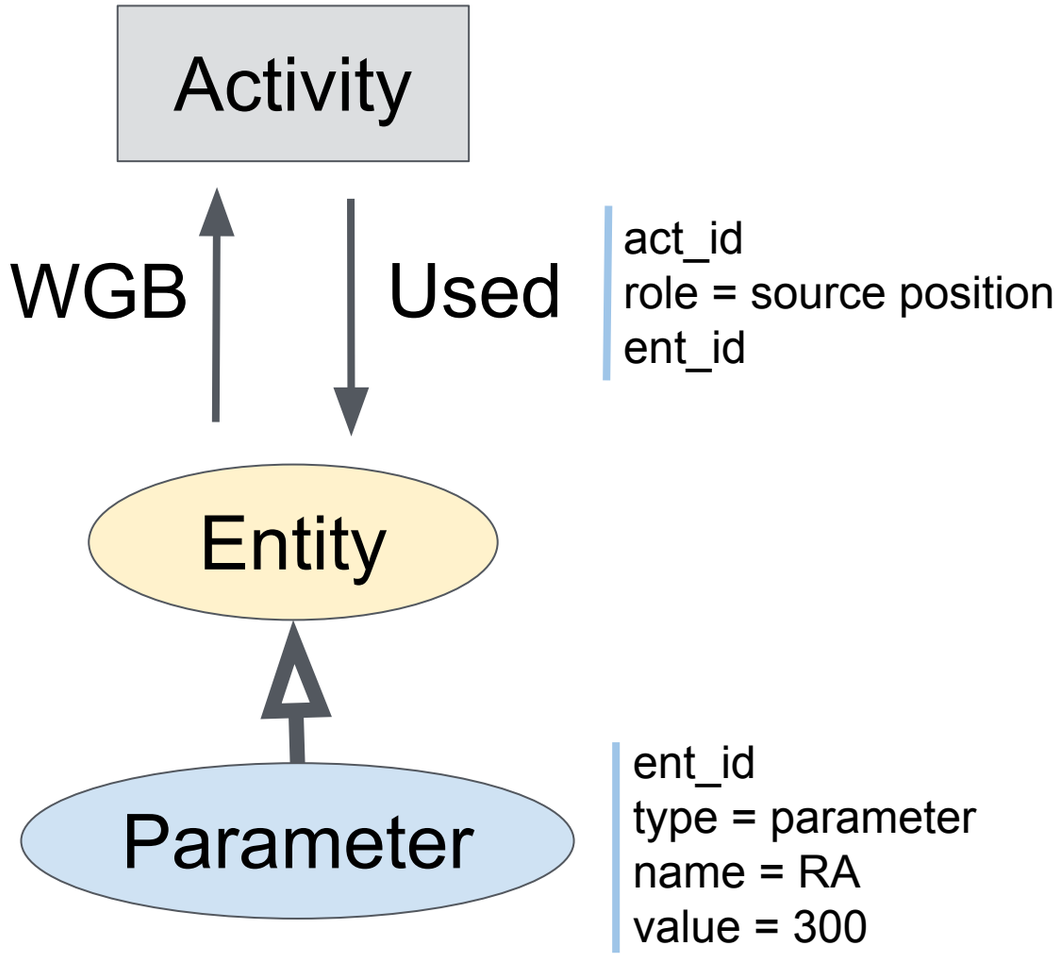
Parameter (section 2.2.7)

name = RA
unit = deg
ucd = pos.eq.ra
utype = ...
description = source position

name = RA
unit = deg
ucd = pos.eq.ra
utype = ...



act_id
name = RA
value = 300



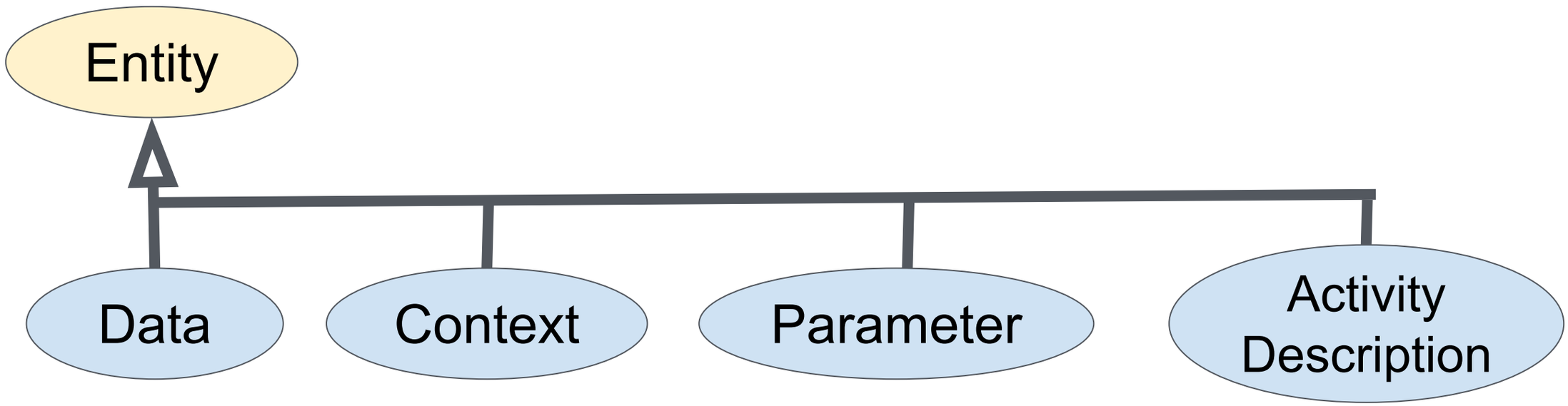
act_id
role = source position
ent_id

ent_id
type = parameter
name = RA
value = 300

- Minimal representation
- logical place for configuration

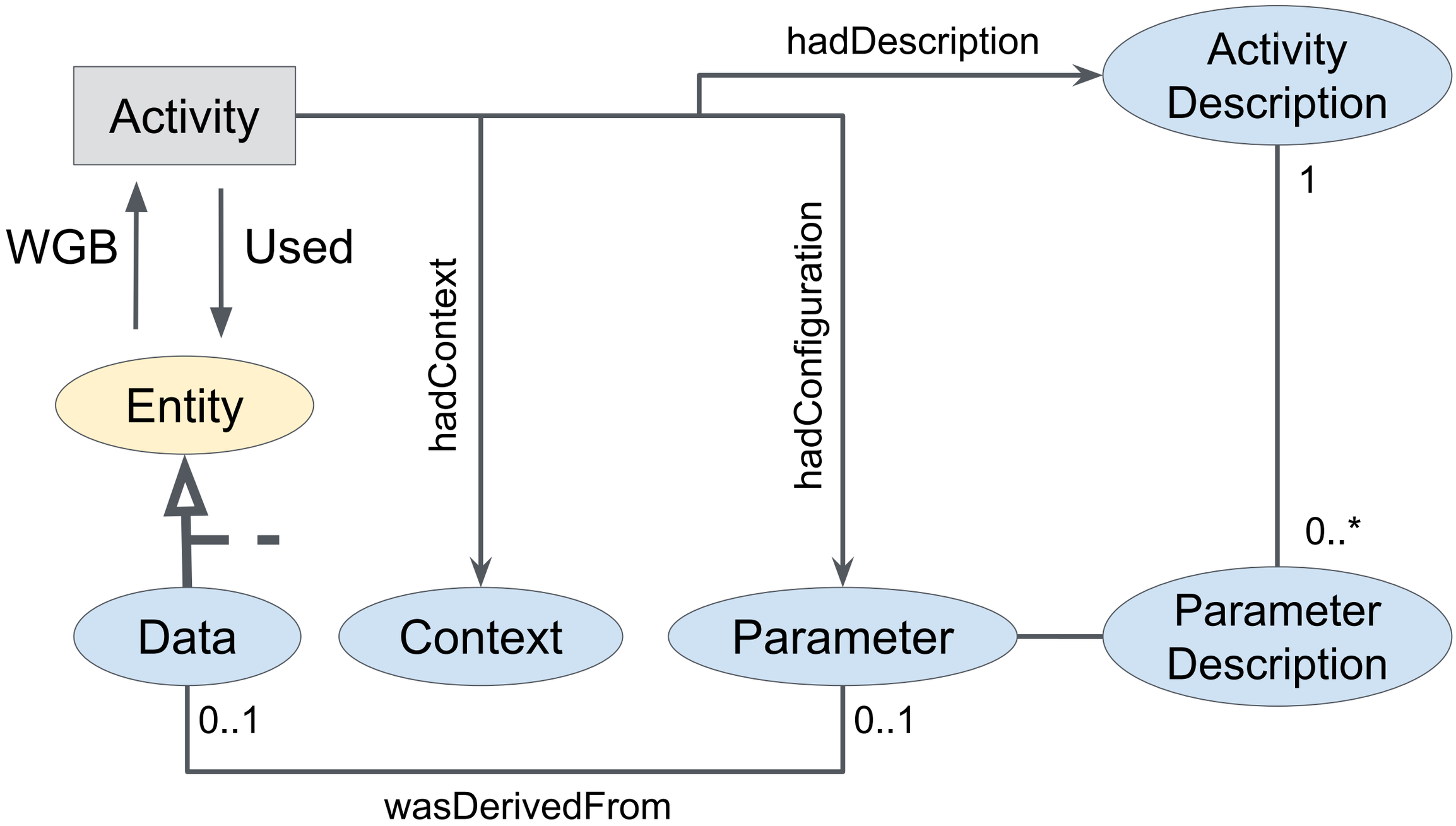
- Reusable (e.g. as a pointing position)
- Provenance of the parameter

Specialization of entities



- **Entity**: An entity is a physical, digital, conceptual, or other kind of thing with some fixed aspects; entities may be real or imaginary. (W3C PROV definition)
- **Data**: digital, machine-readable information in some content that will be used/transformed/analyzed... Could be a cell or a column in a table, a file, an image, a cube... The **value** attribute could directly transport this information, or the **location** attribute directs to it.
- **Document**: information presented in a human readable form.
- **Thing**: a physical object, such as a tool, an instrument, a telescope...
- **ActivityDescription/Plan**: explanations on the activity, main contact(s), inputs expected, output produced...
- **ConfigFile:** file containing configuration information for the activity.
- **Parameter:** configuration of the activity before execution as a key=value parameter in the IVOA framework.
- **AmbientConditions**: common, prevailing, and uncontrolled atmospheric and weather conditions in a room or place that influence the activity
- **InstrumentConfiguration:** description of how the structure of the instrument and how it is set up before an activity starts.
- **ExecutionEnvironment**: describes a particular execution platform, such as an operating system or a database management system. Execution environments are used to describe the context in which the execution of an activity takes place. Execution environments could also describe the computing hardware of a system.

Specialized relations



Serializations - W3C PROV formats

```
<prov:document xmlns:ctadata="ivo://vopdc.obspm/cta#" xmlns:ctajob
  <prov:activity prov:id="ctajobs:ctbin">
    <prov:startTime> 2016-03-13T23:44:46 </prov:startTime>
    <prov:endTime> 2016-03-13T23:44:56 </prov:endTime>
  </prov:activity>
  <prov:agent prov:id="cta:consortium">
    <prov:type xsi:type="xsd:string"> Organization </prov:type>
  </prov:agent>
  <prov:wasAssociatedWith>
    <prov:activity prov:ref="ctajobs:ctbin" />
    <prov:agent prov:ref="cta:consortium" />
  </prov:wasAssociatedWith>
  <prov:entity prov:id="uwsdata:parameters/inobs" />
  <prov:used>
    <prov:activity prov:ref="ctajobs:ctbin" />
    <prov:entity prov:ref="uwsdata:parameters/inobs" />
  </prov:used>
  <prov:entity prov:id="uwsdata:results/outcube" />
  <prov:wasGeneratedBy>
    <prov:entity prov:ref="uwsdata:results/outcube" />
    <prov:activity prov:ref="ctajobs:ctbin" />
  </prov:wasGeneratedBy>
  <prov:wasDerivedFrom>
    <prov:generatedEntity prov:ref="uwadata:results/outcube" />
    <prov:usedEntity prov:ref="uwsdata:parameters/inobs" />
  </prov:wasDerivedFrom>
  <prov:entity prov:id="uwsdata:results/logfile" />
  <prov:wasGeneratedBy>
    <prov:entity prov:ref="uwsdata:results/logfile" />
    <prov:activity prov:ref="ctajobs:ctbin" />
  </prov:wasGeneratedBy>
  <prov:wasDerivedFrom>
    <prov:generatedEntity prov:ref="uwsdata:results/logfile" />
    <prov:usedEntity prov:ref="uwsdata:parameters/inobs" />
  </prov:wasDerivedFrom>
</prov:document>
```

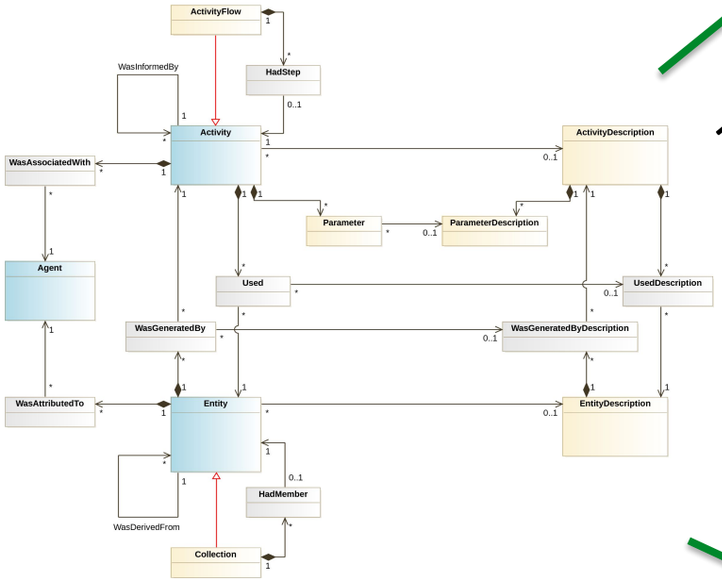
```
{
  - wasAssociatedWith: {
      - _:id1: {
            prov:agent: "cta:consortium",
            prov:activity: "cta:anactools_v1.1"
        }
    },
  - agent: {
      - cta:consortium: {
            prov:type: "Organization"
        }
    },
  - entity: {
        uwsdata:results/fit_results: { },
        uwsdata:results/configfile: { },
        uwsdata:results/butterfly: { },
        uwsdata:results/spectrum_plot: { },
        uwsdata:results/spectrum: { }
    },
  - prefix: {
        uwsdata: "https://voparis-uws-test.obspm.fr/rest
        cta: "http://www.cta-observatory.org#",
        voprov: "http://www.ivoa.net/ns/voprov#"
    },
  - activity: {
      - cta:anactools_v1.1: {
            prov:startTime: "2016-04-07T00:26:00",
            prov:endTime: "2016-04-07T00:27:15"
        }
    },
  - wasGeneratedBy: {
      - _:id5: {
            prov:entity: "uwsdata:results/butterfly",
            prov:activity: "cta:anactools_v1.1"
        },
      - _:id4: {
            prov:entity: "uwsdata:results/fit_results",
            prov:activity: "cta:anactools_v1.1"
        },
```

Serializations - VOTable

```
<?xml version="1.0" encoding="UTF-8"?>
<VOTABLE version="1.2" xmlns="http://www.ivoa.net/xml/VOTable/v1.2"
    xmlns:ex="http://www.example.com/provenance"
    xmlns:ivo="http://www.ivoa.net/documents/rer/ivo/"
    xmlns:voprov="http://www.ivoa.net/documents/dm/provdm/voprov/"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.ivoa.net/xml/VOTable/v1.2 http://www.ivoa.net/xml/VOTable/VOTable-1.2.xsd">
<RESOURCE type="provenance">
    <DESCRIPTION>Provenance VOTable</DESCRIPTION>
    <TABLE name="Usage" utype="voprov:used">
        <FIELD arraysize="*" datatype="char" name="activity" ucd="meta.id" utype="voprov:Usage.activity"/>
        <FIELD arraysize="*" datatype="char" name="entity" ucd="meta.id" utype="voprov:Usage.entity"/>
        <DATA>
            <TABLEDATA>
                <TR>
                    <TD>ex:Process1</TD>
                    <TD>ivo://example#DSS2.143</TD>
                </TR>
            </TABLEDATA>
        </DATA>
    </TABLE>
    <TABLE name="Generation" utype="voprov:wasGeneratedBy">
        <FIELD arraysize="*" datatype="char" name="entity" ucd="meta.id" utype="voprov:Generation.entity"/>
        <FIELD arraysize="*" datatype="char" name="activity" ucd="meta.id" utype="voprov:Generation.activity"/>
        <DATA>
            <TABLEDATA>
                <TR>
                    <TD>ivo://example#Public_NGC6946</TD>
                    <TD>ex:Process1</TD>
                </TR>
            </TABLEDATA>
        </DATA>
    </TABLE>
    <TABLE name="Activity" utype="voprov:Activity">
        <FIELD arraysize="*" datatype="char" name="id" ucd="meta.id" utype="voprov:Activity.id"/>
        <FIELD arraysize="*" datatype="char" name="name" ucd="meta.title" utype="voprov:Activity.name"/>
        <FIELD arraysize="*" datatype="char" name="start" ucd="" utype="voprov:Activity.startTime"/>
        <FIELD arraysize="*" datatype="char" name="stop" ucd="" utype="voprov:Activity.endTime"/>
        <DATA>
            <TABLEDATA>
                <TR>
                    <TD>ex:Process1</TD>
```

Serialization context

IVOA DM



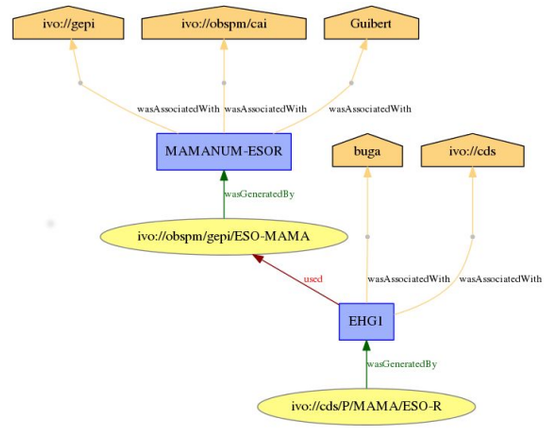
All classes defined in the specification

Translation

W3C PROV View

PROV-JSON
PROV-N
PROV-XML

ProvSAP



W3C Tools
Provenance suite,
Prov-Python

Translation

ProvTAP

IVOA View

VOTable
JSON
FITS

TopCat

TapHandle

Serializations - ActivityDescription

```
<RESOURCE ID="gammapy_maps" name="gammapy_maps" type="meta" utype="voprov:ActivityDescription">

    <DESCRIPTION>Use gammapy to generate a count map from a list of observations</DESCRIPTION>
    <!-- Service Descriptor -->
    <PARAM name="accessURL" datatype="char" arraysize="*" value="https://voparis-uws-test/rest/gammapy_maps" />
    <PARAM name="standardID" datatype="char" arraysize="*" value="ivo://ivoa.net/std/SODA#1.0" />
    <!-- Activity Description -->
    <PARAM name="type" datatype="char" arraysize="*" value="None" utype="voprov:ActivityDescription.type"/>
    <PARAM name="subtype" datatype="char" arraysize="*" value="None" utype="voprov:ActivityDescription.subtype"/>
    <PARAM name="annotation" datatype="char" arraysize="*" value="Use gammapy to generate a count map from a list of
    <PARAM name="version" datatype="char" arraysize="*" value="None" utype="voprov:ActivityDescription.version"/>
    <PARAM name="doculink" datatype="char" arraysize="*" value="https://luthgitlab.obspm.fr/jlefaucheur/hess_release
    <PARAM name="contact_name" datatype="char" arraysize="*" value="Julien Lefaucheur" utype="voprov:Agent.name"/>
    <PARAM name="contact_email" datatype="char" arraysize="*" value="" utype="voprov:Agent.email"/>
    <!-- UWS job attributes -->
    <PARAM name="executionDuration" datatype="int" value="600" utype="uws:Job.executionDuration"/
    <PARAM name="quote" datatype="int" value="120" utype="uws:Job.quote"/>

    <!-- UWS parameters (Provenance Entities or Parameters) -->
    <GROUP name="InputParams">
        <PARAM ID="obs_ids" arraysize="*" datatype="char" name="obs_ids" value="47802 47803 47804
            <DESCRIPTION>List of runs</DESCRIPTION>
        </PARAM>
        <PARAM ID="RA" datatype="double" name="RA" value="329.7169379" unit="deg"...>
        <PARAM ID="Dec" datatype="double"
        <PARAM ID="nxpix" arraysize="*" da
            <DESCRIPTION>Number of pixels
            <VALUES>
                <MIN value="0"/>
                <MAX value="1000"/>
            </VALUES>
        </PARAM>
        <PARAM ID="nypix" arraysize="*" da
        <PARAM ID="binsz" datatype="float"
    </GROUP>
```

VOTable
DataLink Service Descriptor
UWS Job Description Language
Provenance ActivityDescription

```
    <!-- Used Entities -->
    <GROUP name="Used">
        <GROUP name="obs_ids" utype="voprov:UsedDescription" ref="obs_ids">
            <PARAM arraysize="*" datatype="char" name="role" utype="voprov:UsedDescription.role" value="DL3"/>
            <PARAM arraysize="*" datatype="char" name="location" utype="voprov:EntityDescription.location" value=""/
            <PARAM arraysize="*" datatype="char" name="content_type" utype="voprov:EntityDescription.content_type" v
        </GROUP>
    </GROUP>

    <!-- Generated Entities / UWS results -->
    <GROUP name="Generated" utype="voprov:WasGeneratedBy">
        <GROUP name="count_map" utype="voprov:EntityDescription">
            <DESCRIPTION>Count map</DESCRIPTION>
            <PARAM arraysize="*" datatype="char" name="role" utype="voprov:UsedDescription.role" value="DL4 image"/>
            <PARAM arraysize="*" datatype="char" name="default" utype="voprov:Entity.id" value="count_map.fits"/>
            <PARAM arraysize="*" datatype="char" name="content_type" utype="voprov:EntityDescription.content_type" v
        </GROUP>
        <GROUP name="count_preview" utype="voprov:EntityDescription">
            <DESCRIPTION>Count map preview</DESCRIPTION>
```

Conclusions

- Many sections in the draft are stable
- ProvSAP and ProvTAP moved to DAL drafts
- Implementation note based on many use cases
- Still some open questions:
  - modeling of Parameter
  - relations with Description classes
  - mapping for valid W3C serialization without loss
- Next steps
  - move to RFC track before next IVOA meeting