Time Series Data using Sparse Data Cube Model

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Outline

1. Why Data Cube for Timeseries?
2. Supported use cases
3. Discovery
4. Extensions ?
5. How to continue ?

SimpleTimeSeries

- Insufficient for describing multiple axes
- Not flexible
- Not easily extensible

Overloading SSAP

- SVO Corot data 2008, 2010 Nara,
- CZVO 2013 Heidelberg, datalink 2014 Madrid, Topcat/Aladin/Splat demo Sydney
- Similar data structure, but ...
  - Misleading metadata (spectral=time)
  - Need to use non-sense attributes for timeseries
  - Future development (spectral vs. timeseries goals -special use cases ?)

Sparse Cube

- *“Sparse data are commonly used for higher-dimensional cubes, and are frequently sparse along one or more axes. For example, a multi-band image has 7 data at only a few given spectral coordinates, (each corresponding to a spectral bandpass). A spectral (or velocity) data cube may contain data for a number of widely spaced spectral bands, each of which may differ in the spectral resolution and number of channels****. A time cube likewise may contain data, either individual points, or time series, arbitrarily spaced along the time axis with time regions where no data was taken****. A multiobject spectral data cube may be sparse in the spatial plane. Event data can be considered a data cube which is sparse in all measurement axes.”*(N-Dimensional Cube Model)

Sparse Cube

- Can describe any timeseries axes.
- Is flexible
- Is extensible (we just define mandatory axes)

Science use Cases for Time Series

- Use cases - (2012-10-20, Enrique Solano)
  http://wiki.ivoa.net/twiki/bin/view/IVOA/CSPTimeSeries
- 3 groups of requirements
  - Group A: Combine photometry and light curves of a given object/list of objects in the **same photometric band**
  - Group B: Combine photometry and light curves of a given object/list of objects in **different photometric bands**
  - Group C: Time series **other** than light curves

Combine light curves in same photometric band

- Use Case #1: Supernova classification using the light curve
  - Description: The visual light curves of the different supernova types vary in shape and amplitude, based on the underlying mechanisms of the explosion, the way that visible radiation is produced, and the transparency of the ejected material.
  - Requirements
    - Combine photometry and light curves of a given object in the same photometric band
    - Show me a list of data that satisfies
    - Target= SN 2011FE
    - Datatype= Photometry or TimeSeries/lightcurves
    - Axes include time
    - Axes include brightness
    - Information on photometric band (zero point, transmission curve of the filter)

Use case #1 – Datatype= Photometry or TimeSeries/lightcurves


```xml
<?xml version='1.0' encoding='utf-8'?>
<VOTABLE version="1.2" xmlns="http://www.ivoa.net/xml/VOTable/v1.2" xmlns:spec="http://www.ivoa.net/xml/SpectrumModel/v1.01" xmlns:xsi="
http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.ivoa.net/xml/VOTable/v1.2 http://vo.ari.uni-heidelberg.de/docs/
schemata/VOTable-1.2.xsd">
    <DESCRIPTION>Identified objects on DK-154 surveys</DESCRIPTION>
    <RESOURCE>
        <TABLE name="tsinstance">
            <GROUP utype="Cube">
                <GROUP utype="Dataset">
                    <PARAMref ref="asatusslgndn" utype="Type"/>
                    <PARAMref ref="apetggslgndn" utype="Subtype"/>
                    <PARAMref ref="ahutggslgndn" utype="dataProductType"/>
                </GROUP>
```


cube
sparsecube
timeseries

Use case #1 - Axes include time, Axes include brightness, information on photometric band

```
<GROUP utype="Cube.Char">
    <GROUP utype="NDPoint">
        <GROUP ucd="meta.main" utype="TimeAxis">
            <FIELDref ref="HJD" utype="Coverage.Location.Coord"/>
            <PARAMref ref="apdtggslgndn" utype="Bounds.Limits.StartTime"/>
            <PARAMref ref="apttggslgndn" utype="Bounds.Limits.StopTime"/>
        /GROUP>
        <GROUP ucd="meta.main;phot.mag" utype="ObservableAxis">
            <FIELDref ref="MAG"/>
            <FIELDref ref="MAGERR"/>
        </GROUP>
        <GROUP ucd="pos.eq" utype="SpatialAxis">
            <PARAMref ref="raj2000" utype="Coverage.Location.Coord.Position2D.Value2.C1"/>
            <PARAMref ref="dej2000" utype="Coverage.Location.Coord.Position2D.Value2.C2"/>
        </GROUP>
        <GROUP ucd="em.wl;instr.bandpass" utype="SpectralAxis">
            <PARAMref ref="band_name" utype="CoordSys.Band.Name"/>
            <PARAMref ref="band_description" utype="CoordSys.Band.Description"/>
            <PARAMref ref="band_low" utype="Coverage.Bounds.Limits.Interval.Lolim"/>
            <PARAMref ref="band_high" utype="Coverage.Bounds.Limits.Interval.Hilim"/>
        </GROUP>
    </GROUP>
UP>
```

N-dimensional points

Grouping information for TimeAxis

Data in the axis

Metadata of the axis

Reference to FIELD element

SpatialAxis has only one value - central ra,dec of the light curve

SpetralAxis has only one value - bandpass of the light curve

Combine light curves of a given object/list of objects in different photometric bands

- Use Case #5: Follow-up characterisation of supernovae (based on Zhang et al. arXiv:1208.6078v1)
  - Description: Light curves at different wavelength provide different information allowing a better understanding of the physical processes related to the supernovae explosion.
  - Requirements
    - Combine photometry and light curves of a given object in the same photometric band. Repeat this for all the available bands.
    - Show me a list of data that satisfies
    - Target= SN 2010JL
    - Datatype= Photometry or TimeSeries/lightcurves
    - Axes include time
    - Axes include brightness
    - Information on photometric band (zero point, transmission curve of the filter)

Use case #5 – object/list of objects in different photometric bands

```
<GROUP utype="Cube.Char">
    <GROUP utype="NDPoint">
        <GROUP ucd="meta.main;time.epoch;pos.heliocentric" utype="TimeAxis">
            <FIELDref ref="HJD" utype="Coverage.Location.Coord"/>
            <PARAMref ref="apdtggslgndn" utype="Bounds.Limits.StartTime"/>
            <PARAMref ref="apttggslgndn" utype="Bounds.Limits.StopTime"/>
        </GROUP>
        <GROUP ucd="meta.main;phot.mag" utype="ObservableAxis">
            <FIELDref ref="MAG"/>
            <FIELDref ref="MAGERR"/>
        </GROUP>
        <GROUP ucd="pos.eq" utype="SpatialAxis">
            <FIELDRef ref="raj2000" utype="Coverage.Location.Coord.Position2D.Value2.C1"/>
            <FIELDRef ref="dej2000" utype="Coverage.Location.Coord.Position2D.Value2.C2"/>
        </GROUP>
        <GROUP ucd="em.wl;instr.bandpass" utype="SpectralAxis">
            <FIELDref ref="band_name" utype="CoordSys.Band.Name"/>
            <FIELDref ref="band_description" utype="CoordSys.Band.Description"/>
            <FIELDref ref="band_low" utype="Coverage.Bounds.Limits.Interval.Lolim"/>
            <FIELDref ref="band_high" utype="Coverage.Bounds.Limits.Interval.Hilim"/>
        </GROUP>
    </GROUP>
</GROUP>
```

List of objects - multiple central ra, dec

Different bands - data instead of parameter

Time series other than light curves

- Use Case #6: Exoplanet studies using radial velocities (based on Lagrange et al. 2012)
  - Description: Using high precision HARPS data collected over 8 years since 2003, beta Pic radial velocities have been measured and analyse to put direct constrains on the mass of beta Pic b and to search for additional jovian planets on orbits closer than typically 2 AU.
  - Show me a list of data that satisfies
    - Datatype= TimeSeries/radial velocity curves
    - Axes include time
    - Axes include radial velocity

Use Case #6: axes include time, axes include radial velocity

```xml
<GROUP utype="Cube.Char">
    <GROUP utype="NDPoint">
        <GROUP ucd="meta.main;time.epoch;pos.heliocentric" utype="TimeAxis">
            <FIELDref ref="HJD" utype="Coverage.Location.Coord"/>
            <PARAMref ref="apdtggslgndn" utype="Bounds.Limits.StartTime"/>
            <PARAMref ref="apttggslgndn" utype="Bounds.Limits.StopTime"/>
        </GROUP>
        <GROUP ucd="meta.main;phys.veloc;pos.heliocentric" utype="CustomAxis">
            <FIELDref ref="radial_velocity"/>
            <FIELDref ref="radial_velocity_err"/>
        </GROUP>
    </GROUP>
</GROUP>
```

We can have as many as we want, what's in the axis is identified by ucd

Discovery

- Obscore has
  dataProductType =timeseries

- Obscore 1.1 can describe lengths of axes (spectral, time, spatial) and other metadata by default

- Will provide cube with all points, DataLink will be used for cutouts

Possible Extensions

- Accref to file (raw or flatfielded ?)
- Error bars (MAGERR) – filtering in DL
- DataLink to SIAP cutout of star
- DataLink to preview
- Datalink to joined info – e.g. powerspectrum, phased curve
- Complete Provenance (TELAZ, AIRMASS,
- Periods (array ?)
- Dynamically generated LC (DK154)

Use cases TBD and Questions to be asked

- Which Axis is Main (display in TOPCAT, SPLAT-VO)?
- Do we need Period inside? – on-the-fly, L3 prod
- Synthetic Light Curves – what metadata ? (e.g RR Lyr)
- Complex visibility in radio ?
- If RV curve how encode gamma velocity on 1 LC ?
- Should we use 80/20 + Matthew's IVOA development criterium ?
- ---
- Should we start new use cases census or start work ??
- (CSP : It is priority – Multidimension+Time domain)
- We have both – but will be big consumers satisfied ?

Conclusions

- Dataset.dataProductType=timeseries -> we need at least one TimeAxis in NDPoint

- 0..n number of other axes (SpatialAxis, SpectralAxis, ObservableAxis, CustomAxis)

- Metadata vs. data:
  - PARAM elements – common data for whole timeseries
  - FIELD elements – multiple bands, multiple objects, actual data

- If an axis has one value, we can still describe it in the NDPoint (one bandpass in SpectralAxis)

Questions

- Does cubeDM support your usecases?
- Does obscore discovery support your usecases?
- Why would you not use this approach?

(Static) DEMO
of OSPS (DK154)