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IVOA DataLink Protocol Version 1.0

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Status of this Document

Here is an IVOA Note document along the lines of the *Datalink* concepts discussed in the IVOA DAL working group [1] and based on discussions with the High Energy physics science team in Strasbourg Observatory [2] as well as resource linking requirements within Aladin.

1 Introduction

This protocol defines a new category of services allowing to link datasets with various resources such as other related datasets, metadata or other services. Its specifity is to provide a binding mechanism and metadata structure necessary to describe connected datasets or secondary data for independant datasets discovered in previous VO operations. Data product linking is explored here in the context of two main use-cases that are explained in details in section 3. Both have been implemented as prototypes (see Appendix). Requirements are identified and listed in section 4. Section 6 presents a proposal for a data-link service protocol with on one hand, static parameters as defined in IVOA existing protocols, and on the other hand self-described parameter sets for the definition of any kind of linked service.

The purpose of this document is to provide the outline of a data-link protocol supporting these particular use cases and supporting functionalities which are relevant for the common development of a data-link protocol in the IVOA scope.

2 DataLink within overall VO Architecture

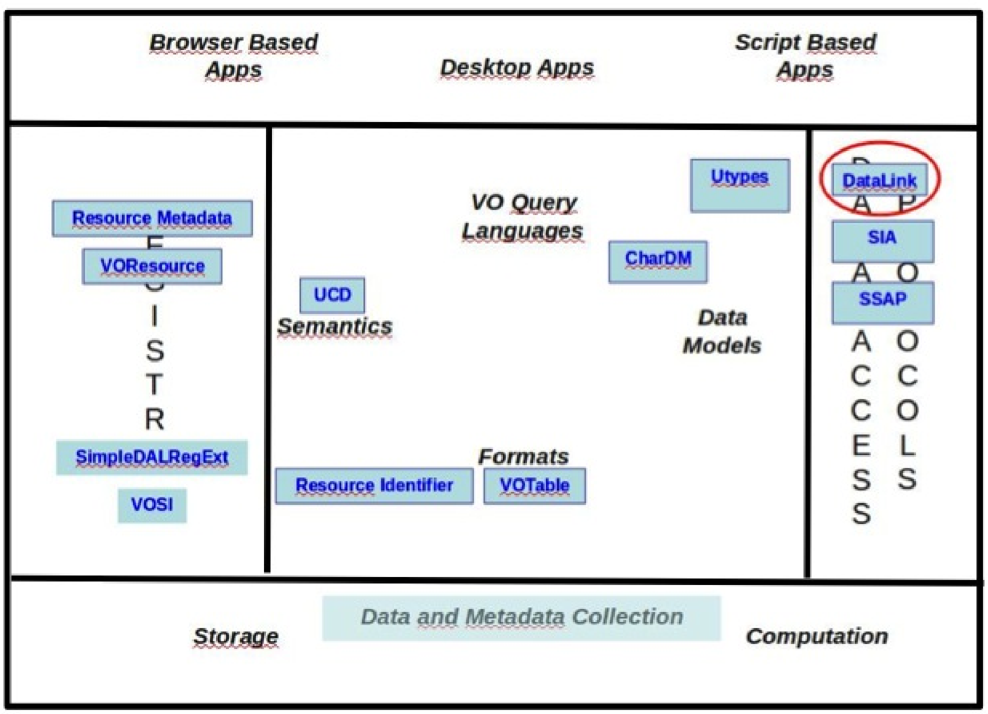

Figure 1: *DataLink* in the global VO architecture

Datalink is one of the acces protocols in close relationships with other protocols such as ObsTAP, SIAP, and SSAP as is illustrated by figure 1.

3 Use Cases

3.1 Exploring and Selecting X-ray Observational Data Using Preview Facilities

One of the main goals for X-ray data end-user interfaces of is to provide users with tools helping to select individual X-ray sources according to their spectral types or to some other physical characteristics. The selection cannot be only done against keywords found within a database. It often a requires visual interpretation of graphs or pictures revealing the nature of the source (spatial environment, spectral features, temporal behaviour, etc .). These pictures and plots can be precomputed and stored into a database, and, in some cases, they must be computed on-the-fly according to users parameters. This kind of enhanced quick view facilities is a relevant use case for elaborating some aspects of the *Datalink* protocol. Details of the prototype service implemented for XMM-Newton images [3] are given in Appendix 1.

3.2 Linking Image Data with Related Resources

The Aladin client browser offers to navigate in the Healpix sky representation in order to locate and select data of interest at a specific sky position. The view is a regridded image at one particular scale of the selected region. Data linking can be used here to bind original observational data sets, at full resolution, and access to further information like for instance image progenitors, calibration files, etc. For multidimensional data , like cubes provided in radio or IFU data collections, data extraction and cut-out services are needed. These functionalities can be implemented in data-link services too. We have developed a prototype for a test Aladin server, that illustrates some of these functionalities. See Appendix 2 for details .

4 DataLink Requirements

The VO protocols currently implemented return data selections either as simple data (spectra, images ...) or as lists of catalog entries. It is never possible to associate data with the searched observations. Associated data may be provided by other services, but at the cost of complex queries (e.g. ADQL joins with TAP) and great difficulties to restore by hand the file binding. This limitation is very restrictive in many cases:

- **Retrieving other data formats**: VO protocols provides reference for retrieval of the dataset in one single format.*Datalink* can provide other formats (e.g. fits instead of VOTABLE for spectra, etc...)

- **Linking to associated datasets**:*Datalink* could provide associations with various types of datasets;
  - **Progenitors**: Some composite datasets can derive from progenitor data having an high scientific interest. It could be for instance interesting to gain an access to the images used to build a false coloured map.
  - **Preview**: Some data can not be visualized either because of their size (cubes) or because of their content (X-ray spectra). It could be very useful to attach precomputed previews allowing a quick view making easier the evaluation of their scientific content.
  - **Calibration data**: The possibility to attach calibration files or any other ancillary resource to searched data would make easier the delivery of data packages ready to be processed.
- **Metadata**: Each dataset in the response could be more extensively characterised by extra metadata. These metadata could be either standardized by IVOA (full characterisation, Provenance) or proprietary...
  - **Provenance**: All metadata is not necessarily in the FITS header or VOTable metadata. It can be retrieved in ancillary files containing for instance a precise description of their provenance.
  - **Data characterisation**: For an observation, the metadata intended to describe, to evaluate the quality of the data or to set up some pre-processing requires more than atomic values taken out from a FITS header or a VOTable. For instance, to analyse an hyperspectral cube where the PSF varies along all dimensions, we need to characterize the PSF behaviour in addition with the observed spaxels. This behaviour can be given as small cubes attached to each point or region of the data cube. The *DataLink* mechanism would therefore provide the instrumental responses, in conjunction with the observations requested in a query. This meta data are modeled in the IVOA data model *Characterization V2* as variation maps with an access to a remote file or to a specific FITS extension.
  - **Other VO data-model mapping**: several VO clients needs well identified keywords in the data files to work properly. These column definitions are rarely available in databases. A tool binding database columns with the quantities defined by the VO or providing missing meta data could be very useful. This kind of model mapping could be feed by a *Datalink* service.

- **Complex dataset** : Many datasets exposed (e.g. with ObsTAP) are actually complex data sets: bunch of spectra for echelle spectrograph or IFUs, ancillary data associated with science data in the same set, various exposures and instruments for the same field in X-ray data, etc... One typical *Datalink* use case there could be to explode the data set components. It will be appreciated to obtain the list of the content of the dataset and to be able to extract some subpart of the dataset.
- **Links to other VO services**: Linking a dataset to another IVOA service can grant an access to complementary data/metadata. The targeted services can be used either in query mode providing more detailed metadata or in *AccessData* mode with virtual data generation:
  - **Cutout**: If the searched dataset is a bit large, the user has to ask for a subset of data in order to avoid downloading and handling the whole file. With simple protocols such as SIAP, the extraction parameters (ΔRaDec, ΔE, Δt) must be set in the initial query, before the user can see the data.
  - **Regridding**: When the orientation and the sampling of the data is not appropriate for comparisons with other datasets, regridding potentially associated with resampling can be performed.
- **Data references in articles**: Any dataset mentionned in an article and uniquely identified in the VO, for instance by the metadata *PublisherDID* (data set Identifier), could be accessed by VO tools through *Datalink* services.
- **Others**: The list of cases where astronomers can take advantage of accessing linked data is probably huge.

5 Scope of this Proposal

The number of services possibly embedded into a *Datalink* response unlimited. They can target either human users or automated processes. They can use standard VO DAL services, basic HTTP requests or complex Web services (figure 2). Thus, there is no way to model all of them without unnecessarily restricting the scope of *Datalink*. To support this variety of services, the *Datalink* protocol specifies a service container which can be the hub of standard IVOA protocol services or which can represent or accomodate them as well as free self-described protocol services. For the same reason, services accessed by *Datalink* are not necessarily declared in the registry. *Datalink* is a protocol at the edge of the VO. It is designed to support resources in or out of its sphere.

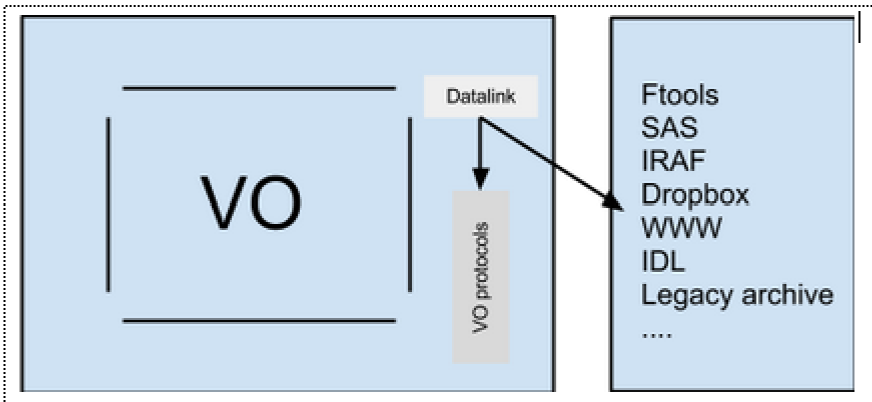

Figure 2: Connecting both VO and non VO services with *Datalink*

Datalink must be designed to ease as much as possible the integration of legacy or ad-hoc services in link services. The protocol layer must remain slim for this reason.

6 The Link Access Mechanism

The *Datalink* mechanism binds each discovered dataset (supposed to support *Datalink*) with a pointer to a data-link server. This server returns a list of links which could be either simple pointers on files (e.g. preview) or pointers on Web services requiring parameters (e.g. cutout). The diagram in figure 3 summarizes the sequence of an access to linked resources.

6.1 Datalink Step by Step

Datalink can be operated in two different ways: as an independant service or as a facility embedded in a standard DAL service. Therefore, a client connecting a VO service must be able to detect by itself a possible support of *Datalink*. That is achieved with the following steps:

- Look for the *Datalink* capability in the service description.
- Look for the identifier to be used to identify individual observations.
- Invoke the *Datalink* service for one or several selected observations.

6.1.1 Service Discovery

The support of the *Datalink* feature can be registered as an independant service or attached to a standard DAL service.

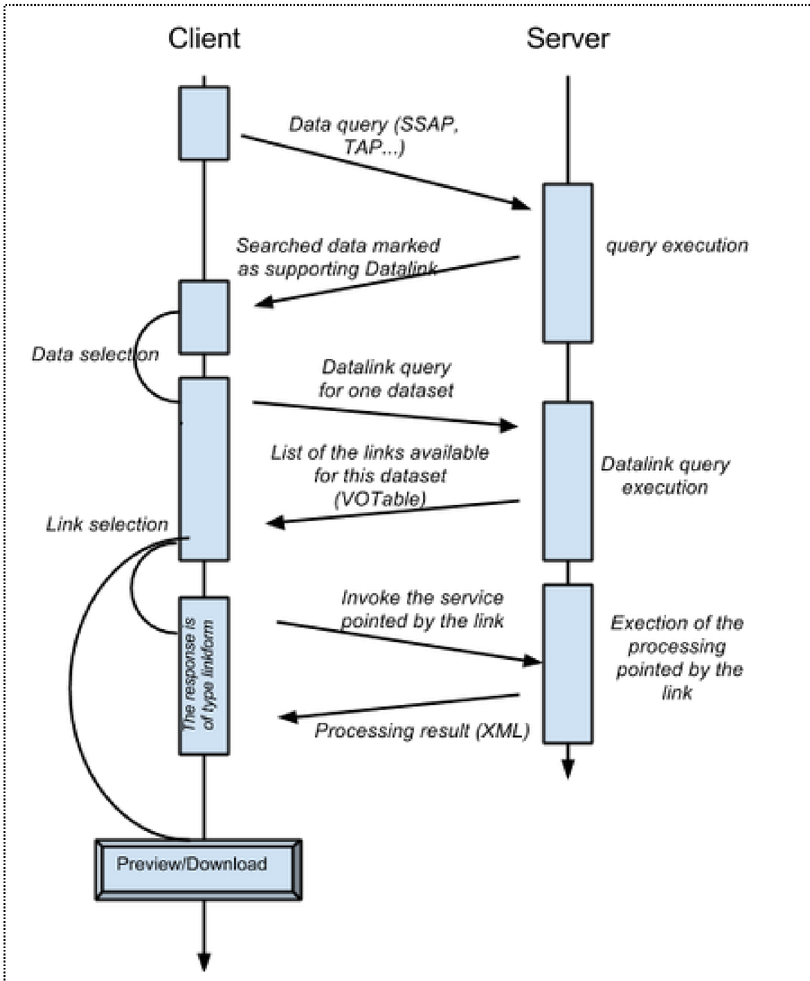

Figure 3: *Datalink* processing

As an independant facility, *Datalink* has to be registered using a VO service *Datalink* extension (TOBD) including the *Datalink* capability. In that case the main query parameter is an IVOA standard dataset identifier such as *PublisherDID*, defined in SSA/spectrum DM, and *ObsCore* DM. A client connecting to this service can use official *PublisherDID* given by another VO service or by any other means (publication, non-VO databases, etc......) . It should be noted that the identifier must be choosen so to easily get the location of the resource in the VO nebulae.

Alternatively a *Datalink* facility can be seen as one feature of a DAL service, a specific capability of that service. In this case, the identifier do not need to be a standardized VO quantity. It can be taken from native data.

Below is an XML sample for this capability. Its describes the URL querying the *Datalink* service attached to that service.

```
<capability xmlns:tr="http://www.ivoa.net/xml/TAPRegExt/v1.0"
   standardID="ivo://ivoa.net/std/DATALINK" >
       <interface xsi:type="vod:ParamHTTP" role="std" version="1.0">
             <accessURL use="full">
              http://my.server.orgm/datalink
             </accessURL>
       </interface>
    <param use="mandatory" std="false">
        <name>nodeID</name>
        <description><![CDATA[
        IVOA identifier of the observation links
        are starting from]]>
        </description>
        <dataType>String</dataType>
    </param>
</capability>
```

Registry capability for *Datalink*

The compulsory parameter *nodeID* identifies one specific observation.

Example derived from the above XML code: Data linked to an observation identified by the ID 1234567890 will be returned by the URL

`http://my.server.org/datalink?nodeID=1234567890`

6.1.2 Observation Identifiers

The protocol must clearly define the way to detect which parameter is used to identify one specific observation. There are several ways to locate this parameter:

- **By name**: That would require VO services to add a specific column to any data collection supporting a *Datalink.Datalink* cannot impose this column to be set, but it can take it into account if it exists.
- **By UType**: There is no generic solution, but SSA and Obstap share the same UType *Curation.PublisherDID* for a standard and unique ivorn for this.
- **By UCD**: Using the first column tagged with the UCD *meta.ref.url; meta.curation* is a good way to do it since this UCD is already attached to the *ObsCore* data model ([4]) column *Obs_publisher_DiD* which contains a unique identifier for the dataset.

In conclusion, to identify the observation, the client must use the content of the first column tagged with the UType *Curation.PUblisherDID*. If there is no such column, the first column with UCD *meta.id;meta.main*. If there is no such column, it has to look for a column named *DataLink*. If there is no such column,*Datalink* is not applicable for the current dataset.

6.1.3 Data Retrieval against Self-described Service

Basically, there are 3 top level categories of links:

- **Links returning data**: The access URL returns the data pointed by the link. The is a simple URL.
- **Parameterized URLs**. In this case, parameters do not need to be described because they are supposed to be known by the client. The range of values to be proposed to the user can be deduced from the meta-data attached to the current observation (e.g. WCS). Simple DAL protocols are typically in this case. If that kind of inference on parameters cannot be achieved, the service must be pushed as a Web service (see next item)
- **Links requiring free extra parameters**. The access url returns an XML document describing the link parameters and the way to build the query and to run it. This is a self-described service

7 Protocol Proposal

7.1 DataLink Response

The *Datalink* response is a VOTable containing the table of the links attached to the selected observation. The meaning of that particular link list can be set as free text in an INFO element. Each row matches one specific link.

The columns (VOTable fields) are described in the table 1. The identifier of the start point observation is a PARAM of the VOTable. It is obviously the same for all the links.

Table 1: VOTable FIELDS defined for a *Datalink* response

Name	Type	ucd	Role	mandatory
publisher_did	param:char array	meta.ref.url; meta.curation	Identifier of the observation from which links are starting from. It is unique for one response.	yes
identifier	field:char array	tbd	Name of the link, helps the client to refer to the link. Free content	yes
servicetype	field:char array	tbd	Type of the service. There are some reserved keywords, but the value is free (see below)	no
method	field:char array	tbd	Communication protocol; default = http	no
format	field:char array	meta.id; class	Any valid Mime type	no
size	field:integer	phys.meta; meta.file	Estimated size of the response	no
access	field:char array	meta.ref.url	URL returning the content of the targeted link	no
description	field:char array	meta.note	Free text description for the semantic of the service	no

Table 2: Supported value for the field *method*

Value	Description	Synchronous
http	Synchronous HTTP access. GET and POST are both supported	yes
get	Synchronous HTTP GET access.	yes
pos	Synchronous HTTP POST access.	yes
uws	Service based on the UWS scheme	no

Both columns *identifier* and *description* are in free text. They are supposed to be human readable or to be helpful for the client to build a clear presentation of the link. The value of the field *method* is taken from a predefined list (table 2) as well as the *servicetype* field (table 3).

Table 3: Supported value for the field *servicetype*

serviceType	extra parameter	Description	Default format
DAL:SIA	no	-	application/x-votable+xml
DAL:SSA	no	-	application/x-votable+xml
DAL:SCS	no	-	application/x-votable+xml
DAL:....	no	-	application/x-votable+xml
webservice	yes	-	text/xml

Self-described services are identified by a *servicetype* value equal to *webservice* which is detailed in the next section. All other types of services directly return data.

7.2 Self-described Webservice Response

The links of type *webservice* must be processed in 2 steps. I) The access URL of the link returns an XML document describing the parameters of the webservice; II) The client get the inputs requested by the link, builds the query and submits it.

The root element of the primary document, named *linkform* in our suggestion prototype, has 3 attributes listed in table 4.

Table 4: Attributes of a *linkform* XML tag

attribute	Role	mandatory
servicetype	The type definition is the same as for the link *servicetype*	yes
identifier	Name of the link. It must be the same as this given by the *Datalink* reply	yes
format	Mime type of the response	might be ignored

The elements *parameter* (see table 5) are identified by a *identifier/UCD* pair. A simple data type can be given to help for the query construction. The boolean attribute *required* tells whether the parameter is mandatory or not.

Table 5: Parameter's attributes

field	Role	mandatory
identifier	the parameter. The identifier is used to build the query: *name=value*	yes
required	boolean set to true if the parameter is required	no, take yes by default
datatype	Data type of the parameter: *string, integer, real* or *boolean*	yes
ucd	UCD of the quantity carried by the parameter	no

It also includes a free text description, a range of values and a default value (see table 6) . The default value allows to get a valid response without user setup. It must be defined. Others values are optional. A *unit* element can be included.

Table 6: Description of a service parameter

field	Role	mandatory
description	Optional description of the role of the parameter	no
unit	Unit of the quantity carried by the parameter	no
range	- type *enum*: contains a list of values. The parameter is supposed to be affected with one of these values. One value must be typed as *default*. - type *range*: must contain a value if type *min* and a value of type *max*. It must contain a value typed as *default*.	yes with at least one default value

The example below (detailed in appendix A) describes a response of a self-described service that fits a power law on an EPIC spectrum [1]. This link requires 3 parameters:

[1]The XMM-Newton spacecraft is carrying a set of three X-ray CCD cameras named the European Photon Imaging Cameras (EPIC).

- **binsize**: The X-ray spectrum needs to be rebinned before applying a model. This parameter gives the number of counts per bin. It is an enumeration of possible values.
- **nh**: Gives the galactic NH (number of atoms of H per cm-2 between the observer and the target).
- **alpha**: Photon index of the power law (dimensionless parameter).

```
<linkform servicetype="download” identifier="PowerLaw” format="image/gif">
    <!--
        database name: ThreeXMM
        database url: http://obs-he-lm:8888/3XMM
        oid: 1160803203386703876
        model: PowerLaw
    -->
    <description>
    Apply a power law model on a XMM-Newton EPIC spectrum
    </description>

    <baseurl>
    http://obs-he-lm:8888/3XMM/fitmodelonspectrum?oid=1160803203386703876&moc
    </baseurl>

    <parameter identifier="binsize" mandatory=”true”
    ucd=”spect.binSize” datatype=”int”>
        <description>Number of counts per bin</description>
        <unit>none</description>
        <range type="enum">
            <value>1</value>
            <value>5</value>
            <value type="default">10</value>
            <value>25</value>
            <value>50</value>
        </range>
    </parameter>

    <parameter identifier="nh" mandatory=”true”
    ucd=phys.abund.X” datatype=”real”>
        <description>Galactical NH</description>
        <unit>1e22cm-2</description>
        <range type="range">
            <value type="min">0</value>
            <value type="max">1</value>
            <value type="default">0.01</value>
        </range>
    </parameter>

    <parameter identifier="alpha" mandatory=”true”
     ucd=”meta.code;spect.index” datatype=”real”>

    <description>Photon index of power law</description>
        <unit>none</description>
        <range type="range">
            <value type="min">1</value>
            <value type="max">9</value>
            <value type="default">1.7</value>
        </range>
    </parameter>
</linkform>
```

Response of a self-described service

The GET query with the default parameters will be for this response :

`http://obs-he-lm:8888/3XMM/fitmodelonspectrum?oid=1160803203386703876&model=powlaw&binsize=10&nh=0.01&alpha=1.7`

Note that the choice of these parameters is not necessarily the best for the science case; it has been made for the demo purpose.

7.3 Error Response

In case of processing error, a standard error VOTable is returned.

```
<VOTABLE … version="1.1">
    <RESOURCE type="results">
        <INFO name="QUERY_STATUS" value="ERROR">
        NO datalink available for node 123456</INFO>
        <INFO name="SERVICE_PROTOCOL" value="1.0">DataLink</INFO>
        <INFO name="REQUEST" value="queryData"/>
        <INFO name="baseUrl" value="http://my.server.com/datalink"/>
        <INFO name="serviceVersion" value="1.0"/>
    </RESOURCE>
</VOTABLE>
```

Example of error response

Appendix A: Concrete Implementation: TAP + Datalink Applied to the EPIC Spectra of XMM-Newton.

There is a real need for tools helping HE astronomers to evaluate online the spectral characteristics of sources of interest. That is not easy yet because source spectra are delivered as raw data. They have often a statistic too poor to be simply calibrated by an automated process. Usually, users download the FITS spectra with calibration data to do their own local processing. This heavy operation could be often skipped if there was a quick look facility. That can be achieved by a Webservice running on selected spectra with a few parameters given by the user. This section presents 2 use cases identified by the HE team of the Observatory of Strasbourg.

Preview of Instrumental Spectra (not implemented yet)

The previews of XMM-Newton spectra are currently precomputed by the mission pipeline. They are only available for sources for which an EPIC spectra has been computed, that is for the brightest sources (more than 500 EPIC counts). A *Datalink* service could extend this service to sources without computed spectra.

Fitting Basic Model on Spectra (implemented)

This service helps users to get the spectral characteristics of sources to evaluate if they are or not good candidates for the studied class of objects. The purpose of the demonstrator shown in this section is to fit online some standard models on candidate spectra. Only two models are proposed here, a power law (with and without Z) and an emission of hot diffuse gas (Mekal). A Web service doing similar processing on HE spectra is available at HEASARC [9].

The back-end Database

The database used here contains 63 EPIC spectra with their calibration data and previews. It has been built with Saada [5]. Both calibration data and previews have been attached to the spectra with the relationship mechanism of Saada. The collection of spectra has an extra column named *Datalink* used by the link server to identify each spectra. The data-link server is a Java servlet specially developed for this example.

The spectra collection has been published in a TAP service which is publickly accessible by Taphandle [7]. A Taphandle extension has been developed to process data links on the client side. [2]

Taphandle end-user interface

When the user clicks on a *Datalink* icon, Taphandle calls the data-link service of the database. The XML response contains 6 links (figure 4). Those which are not of type *webservice*, are presented as HTML anchors.

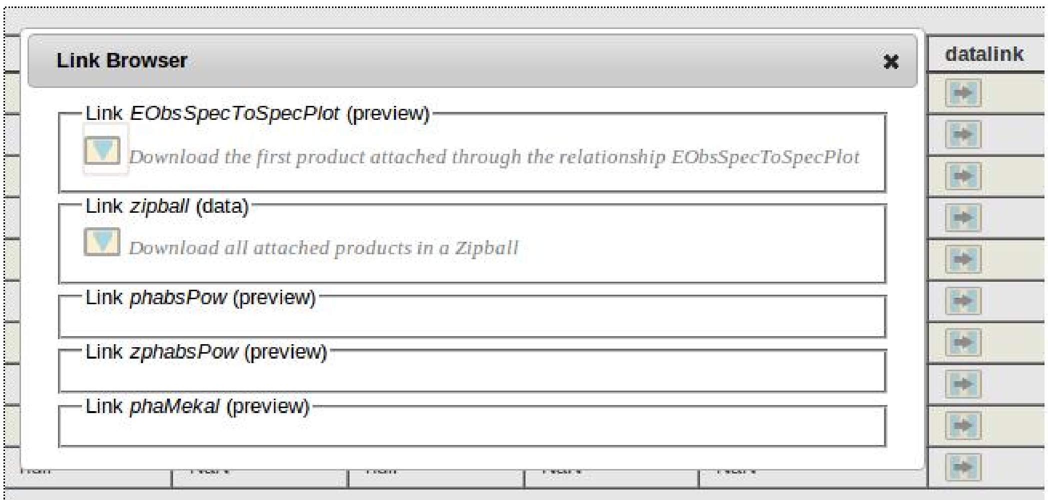

Figure 4: Demo output:*Datalink* window produced by Taphandle

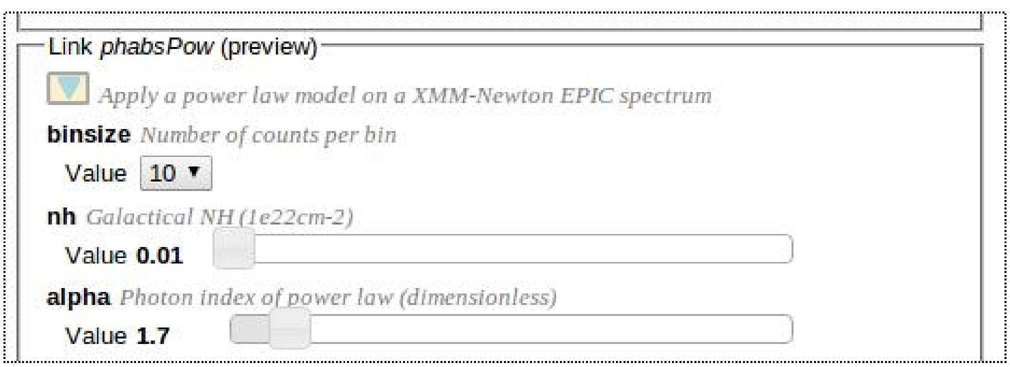

Figure 5: Demo output: Webservice form generated by Taphandle

When the user clicks on the *phabsPow* frame, Taphandle calls the access URL of this link. The response is an *linkform* XML document which is

[2]publickly available at http://saada.unistra.fr/taphandle?url=http%3A//saada.unistra.fr/3xmm/tap

translated into an HTML form (figure 5). The response of that particular request is listed in the previous section.

When the user submits the form, the query is sent to the database which runs a script based on XSpec ([8]) from HEASARC[10]. The resulting plot is displayed by Taphandle (figure 6)

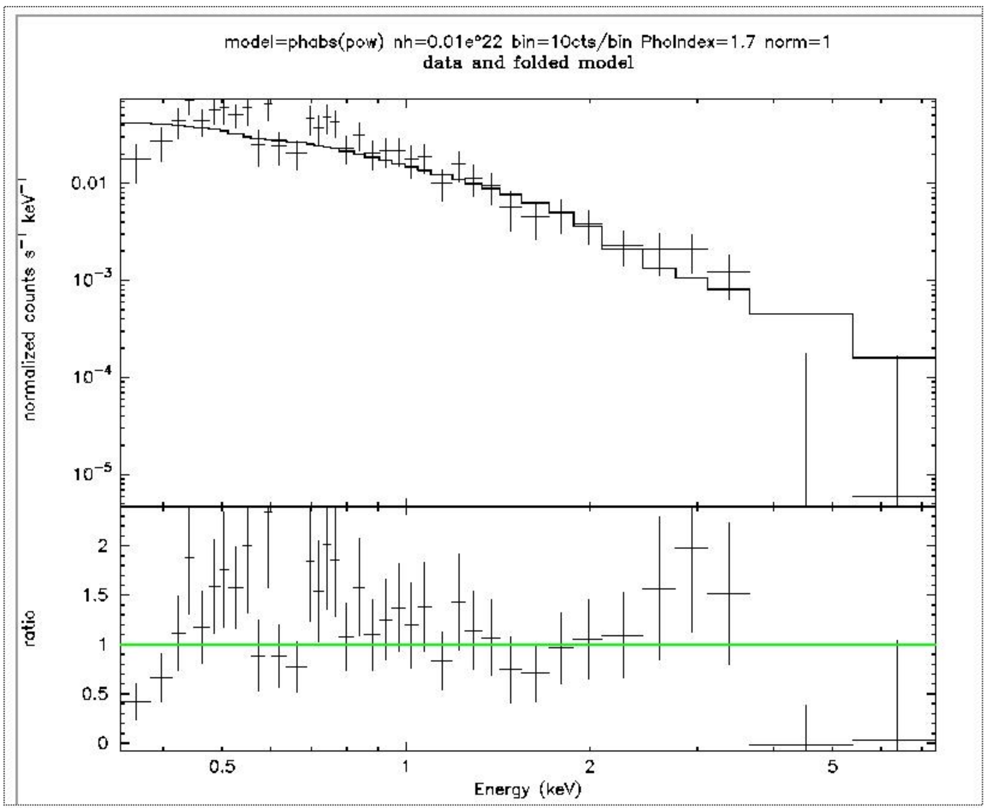

Figure 6: Demo output: A power law fitted on an EPIC spectrum

This *Datalink* service will be a part of the next XCatDB [6] release coming with the 3rd XMM-Newton catalogue (3XMM). Other models or model combinations will be included in it as well as the XSpec processing log which will allow users to assess the relevance of the fit. The goal of this tool is to provide users a first quick look only. For clarity, the service will not handle errors on parameters.

Appendix B: A Concrete Implementation: Aladin HEALPIX use case

Aladin is a VO image application which accesses and display survey images in two very different ways: - By accessing standard image servers (for example SIA servers) based on a two phase (query/retrieval) mechanism, including the CDS Aladin server itself. Individual images are generally individual observations of the survey. The query phase response is a description of the images consistent with VO Standard and datamodels. The main drawback of this approach is the continuity at the individual observation bundaries. But it allows accurate description of the original observations and gives access to archive data which have not been reprocessed.

- By accessing on line to resampled survey pixels organized in HEALPIX hierarchical mesh. This approach allows progressive zooming from full survey coverage down to the smallest areas by continuous refinement of the resolution mesh. But these are reprocessed data and there is currently no standardized metadata attached to them.

The new CDS Aladin data-link service allows to overthrow these drawbacks.

- Each highest resolution mesh in the survey can store the Publisher DID of the original dataset(s) used for computation of HEALPIX pixel values in the mesh.

- The aladin interface can then retrieve the list of Publisher DIDs in a given area and request the data-link service with this list of PublisherDIDS. It will retrieve a VOTABLE with the list of links available for each dataset.

In our prototype we have experimented the following links (see figure 7) for each dataset

- SIA-like response description.

- Fixed size Cutout service on original images

- Full Schmidt plate low resolution previews

- CFHTLS stacks progenitors

Clicking on these links gives the following results :

a) SIA-like query response description (It's possible to retrieve original images as a second step)

b) Direct download into Aladin of a server defined size cutout of the original image

c) Download into Aladin of a preview image of a full Schmidt ESO plate (usefull for studying plate bundaries overlay problems for example)

d) In the CFHTLS survey case, each stack used to build the HEALPIX view results itself from the mosaicking of a bunch of progenitors MEGACAM

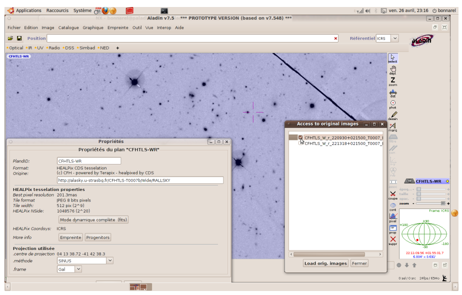

Figure 7: Original images (ID) in an HEALPIX cell

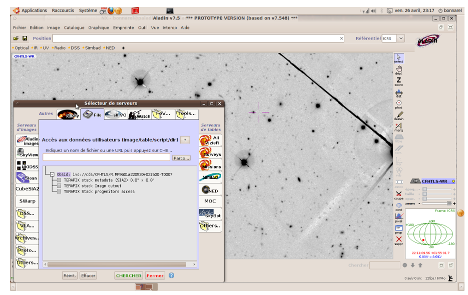

Figure 8: Available Links for original images

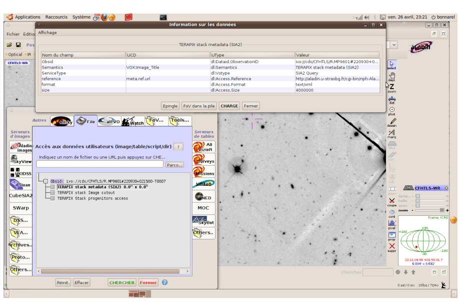

Figure 9: Metadata Link for original image

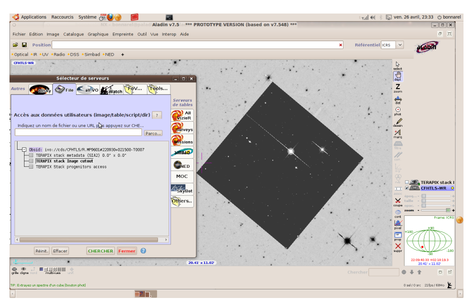

Figure 10: Cutout Links for original image

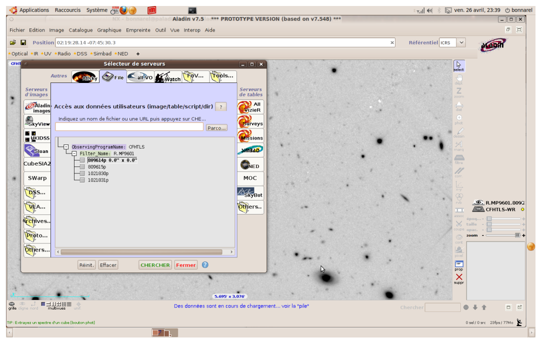

Figure 11: Links giving progenitor list (with access URL) for original image

images. the list of progenitors is displayed within Aladin window and each of them can be downloaded into Aladin from CADC.

The data-link CDS Aladin service is a real service independant from the classical Aladin server in SIA mode. It could be registered as soon as an extension for *Datalink* services is available

The *Datalink* service can be queried from other services, as long as they used the CDS publisher DIDS. For example the list of *PublisherDIDs* could be extracted from publications and browsed via TOPCAT

References

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