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Authors	Vicinanza, Martina; MOLINARO, Marco; ZORBA, SONIA; BIGNAMINI, ANDREA; CALABRIA, NICOLA FULVIO; SMAREGLIA, Riccardo; KNAPIC, Cristina
Affiliation of first author	O.A. Trieste
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Prototype LBT/LUCI ObsCore table

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Authors: Martina Vicinanza, Marco Molinaro, Sonia Zorba, Andrea Bignamini, Nicola F. Calabria, Riccardo Smareglia, Cristina Knapic

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Contents

1 Introduction

The International Virtual Observatory Alliance (IVOA) is an organisation that debates and agrees the technical standard to provide interoperability among different astronomical datasets [1]. For this purpose an Observation Data Model Core Components (ObsCoreDM) has been released defining the core components of basic queryable metadata required for global discovery of observational data through Astronomical Data Query Language (ADQL) queries (see [2]). In this document we may use the ObsCoreDM and ObsCore wording interchangeably, despite the former refers to an actual data model for observational data and the latter is the plain view of it generated for easier tabular query of the observational records described by the former.

The Large Binocular Telescope (LBT) is a pair of two identical 8.4m telescopes mounted side-by-side on a common altitude-azimuth mounting for a combined collecting area of a single 11.8m telescope mounted. It hosts three facility instruments: 1) the Large Binocular Cameras (LBCs); 2) the two Multi-Object Double Spectrograph (MODS); and 3) the two LBT Utility Cameras (LUCI), see [3] for further details on the instruments. The LBT is an international collaboration of the University of Arizona, Italy (INAF: Istituto Nazionale di Astrofisica), Germany (LBTB: LBT Beteiligungsgesellschaft), The Ohio State University, and the Tucsonbased Research Corporation representing the University of Minnesota, the University of Virginia, and the University of Notre Dame.

The archive and distribution systems of raw data between the Large Binocular Telescope Observatory (LBTO) and the partners is supported by the Italian Center for Astronomical Archives (IA2) (see [4,5,6]).

This document presents the first prototype of an IVOA compliant ObsCore table of proper raw data from LBT/LUCI to be published and shared among the astronomical community through both the Table Access Protocol (TAP-1.x) and the Simple Image Access Protocol version 2 (SIAP-2.0).

2 Acronyms

ADQL	Astronomical Data Query Language
ADS	The SAO/NASA Astrophysics Data System
FAIR	Findable, Accessible, Interoperable, Re-usable
FITS	Flexible Image Transport System
INAF	Italian National Institute of Astrophysics
IVOA	International Virtual Observatory Alliance
LBC	Large Binocular Camera
LBT	Large Binocular Telescope
LBTB	LBT Beteiligungsgesellschaft
LBTO	Large Binocular Telescope Observatory
LUCI	LBT Utility Cameras
MJD	Modified Julian Date
MODS	Multi-Object Double Spectrograph
ObsCoreDM	Observation Data model Core (components)
PM	Person Month
SIA	Simple Image Access protocol
TAP	Table Access Protocol
UCD	Unified Content Descriptor
VO	Virtual Observatory

3 Reference documents

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4. NADIR Technical Manual C. Knapic
5. NADIR: A Flexible Archiving System Current Development C. Knapic, M. De Marco, R.Smareglia, M. Molinaro - ASP Conference Series, Vol. 485
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7. http://simbad.u-strasbg.fr/simbad/sim-fid
8."Table Access Protocol", version 1.1, *Dowler, P., Rixon, G., Tody, D., Demleitner, M.*, IVOA Recommendation, http://www.ivoa.net/documents/TAP/20190927/REC-TAP-1.1.html
9. "IVOA Simple Image Access", version 2.0, *Dowler P., Bonnarel F., Tody D.*, IVOA Recommendation, doi:10.5479/ADS/bib/2015ivoa.spec.1223D
10. http://www.ivoa.net/documents/SIA/
11. Luci User Manual https://996a4126-a-79502442-s-sites.googlegroups.com/a/lbto.org/luci/documents-and-li
LUCI_UserMan.pdf?attachauth=ANoY7cpV_Gs25sBIoOE-jOV0rjm7HXEF4rbwWyTlqHJOf-hNDlE5Zg5Yn_uPyFAZA9jxOWl8ake
PDrD1c%3D&attredirects=0

4 ObsCore Data Model

In this section, we briefly give an overview on the mandatory fields of the ObsCore table with their name (more precisely with their TAP column name), recommended units, data type and designation.

Column Name	Unit	Type	Description	Constraint
dataproduct_type	unitless	String	Logical data product type	
calib_level	unitless	enum integer	Calibration level {0,1,2,3,4}	not null
obs_collection	unitless	String	Name of the data collection	not null
obs_id	unitless	String	Observation ID	not null
obs_publisher_did	unitless	String	Dataset identifier given by the publisher	not null
access_url	unitless	String	URL used to access (download dataset)	
access_format	unitless	String	File content format	
access_estsize	kbyte	integer	Estimated size of dataset in kylo bytes	
target_name	unitless	String	Astronomical object observed, if any	
s_ra	deg	double	Central right ascension, ICRS	
s_dec	deg	double	Central declination, ICRS	
s_fov	deg	double	Diameter (bounds) of the covered region	
s_region	unitless	String	Sky region covered by the data product, expressed in ICRS frame	
s_xel1	unitless	integer	Number of elements along the first spatial axis	
s_xel2	unitless	integer	Number of elements along the second spatial axis	
s_resolution	arcsec	double	Spatial resolution of data as FWHM	
t_min	d	double	Start time in MJD	
t_max	d	double	Stop time in MJD	
t_exptime	s	double	Total exosure time	
t_resolution	s	double	Temporal resolution FWHM	
t_xel	unitless	integer	Number of elements along the time axis	
em_min	m	double	Start in spectral coordinates	
em_max	m	double	Stop in spectral coordinates	
em_res_power	unitless	double	Spectral resolving power	
em_xel	unitless	integer	Number of elements along the spectral axis	
o_ucd	unitless	String	UCD of observable (e.g. phot.count)	
pol_states	unitless	String	List of polarization of NULL if not applicable	
facility_name	unitless	String	name of the facility used for this observation	
instrument_name	unitless	String	Name of the instrument used for this observation	

The ObsCore fields for a collection of LBT raw data must be filled according to the previous requirements and under some assumptions that here we recall:

- The **dataproduct_type** field describes the scientific classification of the data product considered. Currently this classification is a controlled list of vocabulary terms such as: image, cube, spectrum, sed, timeseries, visibility, event and measurements. In the case of LBT we treat only image/cube for LBC, image/spectrum for both LUCI and MODS.
- **Calib_level**: according to IVOA standard LBT raw data are described as level 1, instrumental data in a standard format.
- **Obs_collection**: at the moment we collect LUCI data as the LBT/LUCI collection.
- **Obs_id**: at the moment we use the name of a single file as (unique) identifier.
- **Obs_publisher_did**: not delivered yet. This should/could in principle be a resolvable unique identifier for the dataset assigned by the data collection publisher.

- **Access_url**: at the moment we use the same archive URL to retrieve data.
- **Access_format**: we choose image/x-fits-gzip for both image and spectrum (being the latter treated and delivered as an image).
- **Access_estsize**: as explained in the table.
- **Target_name**: we choose to use object names as resolved by Simbad ([7]). This field is left empty when the object name provided by PI is misspelled or missing or unintentionally wrong and a coordinate query with Simbad and/or even with a query on scientific papers thorough ADS portal does not supply a unique target. These cases can be potentially solved having access to PI's proposals, even if this approach still requires a considerable human effort.
- **s_ra**, **s_dec**: as explained in the table.
- **s_fov**: we choose the diameter of a circle inscribed in a bounding box having cutted off the edges of the actual frame (in order to avoid edges effects) when a proper WCS is provided.
- **s_region**: because as archive we do not have the right algorithms to draw the footprint of each scientific frame, we use a bounding box as a precise region with which performs a positional query, when a proper WCS is provided.
- **s_xel1**, **s_xel2**: as explained in the table.
- **s_resolution** is left to NULL because we can not compute the Point Spread Function of the images.
- **t_min**, **t_max**, **t_exptime**: as explained in the table.
- **t_resolution** and **t_xel** are left to NULL, we are not working with timeseries.
- **em_min**, **em_max**: we use nominal values of the energy band of the filters as reported in [3].
- **em_res_power**: as em_min and em_max, for spectrum only.
- **em_xel** is left to NULL, there are no keywords describing this quantity in LUCI or MODS headers.
- **o_ucd**: we use phot.adu.
- **pol_states** is NULL.
- **facility_name**: LBT.
- **instrument_name**: can be LBC, LUCI or MODS.

5 Raw data sample

In this section are described the steps involved in selecting an appropriate (test) sample of raw datasets to turn into a prototype service.

5.1 Metadata

We started to investigate the feasibility of this type of activity with LUCI data because this instrument is heavily used as imager and spectrograph by the LBT community.

According to the current implementation of LUCI metadata, the combination of metadata attributes that allow the classification among images, spectra, acquisition files and darks have been carried out with the help of the Italian LBT reduction data teams. It is composed by 6 keywords: GRATNAME, MASKID, MASKSLOT, MOSPOS, FILTER1 and FILTER2, and selects files as

- dark: if FILTER1='blind' and FILTER2='blind', no matter how other keywords are filled;
- images: if GRATNAME='Mirror' and MASKID='unknown' and (MASKSLOT='unknown' or MASKSLOT='−1') and MOSPOS='no mask in use';
- acquisition files: if GRATNAME='Mirror' and MASKID>0 and MASKSLOT!='N30_FieldStop' and (MOSPOS='mask in turnout' or MOSPOS='mask in fpu');
- spectra: if MASKID>0 and MASKSLOT!='N30_FieldStop' (and GRATNAME!='Mirror' as a check); this particular condition should be enough to select all spectra except fot Adaptive Optics frames.

With acquisition files we refer to an image of the field of interest, taken with a very low exposure time, and the same image but with the slits or masks superimposed on it to verify the correctness of the alignment with the target and/or other astronomical objects (see sect. 2.1 in [11]). Since the ObsCoreDM is meant to describe only high level scientific data products, acquisition files along with dark, flat, and bias would be delivered to the final user as a set of calibration files through DataLink tool once it will be ready to use. At the moment we provide access only to the initial image/spectrum raw data via Virtual Observatory (VO) services as the aforementioned TAP and SIA.

This classification based on metadata fails when the keywords in the headers are not properly filled, e.g.:

- luci2.20160125.0045.fits.gz should be an image but due the presence of the grism the corresponding metadata are GRATNAME='G200 LoRes', MASKSLOT=-1, MASKID='unknown', MOSPOS='no mask in use'; see https://wiki.lbto.org/PartnerObserving/ObsInaf20160125
- luci2.20160130.0078.fits.gz is an acquisition file but the wrong metadata GRATNAME='G200 LoRes', MASKSLOT=12, MASKID='905822.GLASS2c', MOSPOS='mask in turnout' prevent a good classification; see https://wiki.lbto.org/PartnerObserving/ObsInaf20160130

5.2 Calibration and series of observations

Along with the pure scientific files the archiving system ingests all calibrations at real time. By all calibrations we mean both "technical" and "science-related" calibrations. The technical calibrations can be performed during specific periods of the observing semester, and these can be easily excluded from every kind of scientific analysis using the observing schedule, or during an observing night if some issues with instruments (related or not with bad weather) happen. The science-related calibrations are required to reduce raw data, these can be strictly related to a specific target or can be taken with a standard configuration of an instrument. During an observing semester a lot of these frames are taken also due to the peculiar location of the telescope characterized by a very varying weather conditions. In order to optimize the scientific return of an observing campaign, the scientific observer decides by time, in situ, the number of necessary calibrations, their order between different observations or some days in advance or later, as well as for any other cases. Calibrations related to specific targets can be taken more than once if, for example, scientists are obliged to reschedule that specific observation; in some cases re-observation will be performed months later. Calibrations can be repeated during the same night in case of low quality acquisition, or when the observers changes manually the instrument configuration to match the desired requirements, i.e. low counts due to an insufficient exposure time.

Actual observations (both short and long term programs) can be stopped and/or repeated if technical issues happen or due to the weather variability, i.e. increase of the seeing out of the specifications, clouds passing etc. All the scientific frames and the plethora of calibration files are archived blindly. From the metadata analysis alone it is hard to understand and recognize the relationships between good actual observations and calibrations they belong to. Some partners provide detailed public logs (see [8]) of the observation activities for each night, reporting weather condition, status of the instrument(s) during night, targets observed and almost any observative decisions taken by scientists at the telescope. Through the study of these logs it is possible to unlock the analysis of the completed observed targets, at least, using the concept of "completed program" as a first good quality hint for the raw data.

At the state-of-the-art without these logs the analysis of metadata alone is not sufficient to guarantee a reliable selection of proper datasets to be published, especially if we must take into account the different proprietary period of the data of each partner in the past. The aim of this data curation is to classify and well-form the metadata for the publishing, the drawbacks explained in these paragraphs suggest the importance of the human experience over the automation, particularly at the first stage of the data publication although it requires a lot of human effort.

6 Prototype LBT/LUCI ObsCore table

This prototype consists of 14 records, 5 images and 9 spectra, of the target "2MASS J05101100-0328262" taken with LUCI instrument during the 10th February 2015 night, described here: https://wiki.lbto.org/PartnerObserving/ObsInaf20150210 . The images have been taken with the filter H and 4 seconds of time exposure, while the spectra with HK and zJ filters, each of them taken with 300 seconds of exposure. The fields s_fov and s_region have been computed as described in sect. 4, treating spectra as "images" at this stage.

7 VO services

In the following paragraphs we describe the current VO services useful to explore the ObsCore table prototyped in this report.

The ObsCore table is the view over the test data collection. This is seen as a data resource that can be searched and accessed through the VO services seen as interfaces on top of it

7.1 TAP service

The table access protocol (TAP) defines a service protocol for accessing general table data, including astronomical catalogs as well as general database tables. Access is provided for both database and table metadata as well as for actual table data [9].

The ObsCore table can be queryable through the underlying TAP service. It can be queryable with the ADQL language using, i.e., the client TOPCAT, as shown below.

At the moment the TAP is hosted at this URL: http://archives.ia2.inaf.it/vo/tap/lbt/ and it must be inserted by hand in TOPCAT → VO → Table Access Protocol (TAP) Query → TAP URL → Use Service

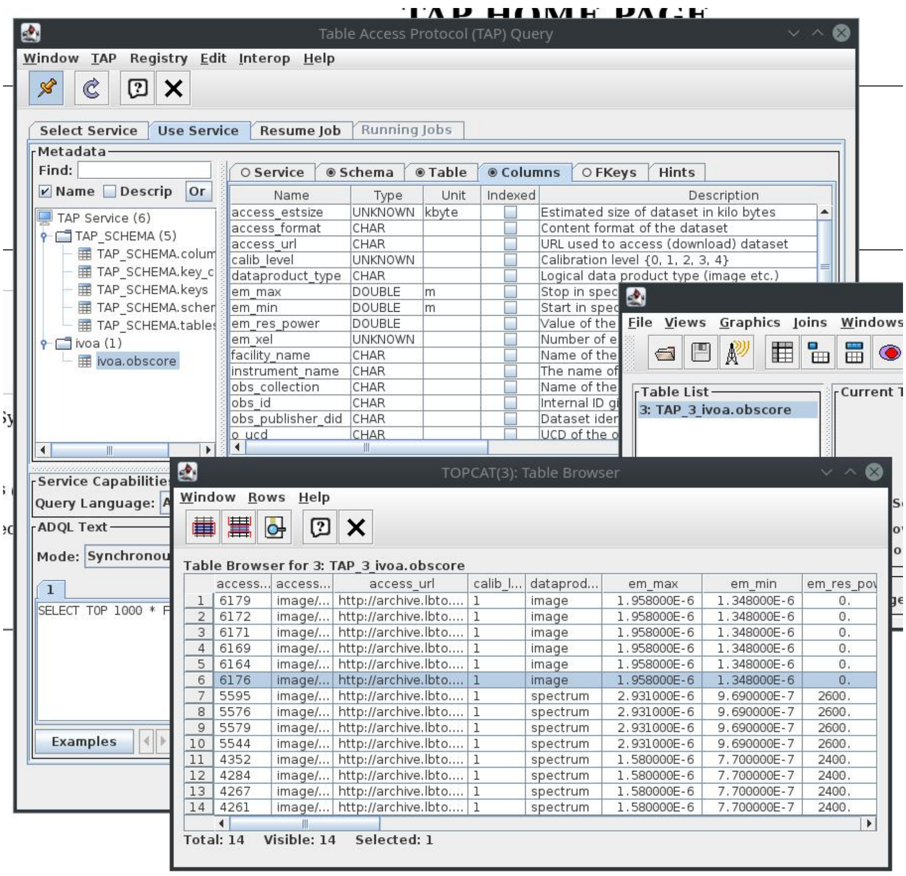

Figure 1:

7.2 SIA service

The Simple Image Access protocol (SIA) provides capabilities for the discovery, description, access, and retrieval of multi-dimensional image datasets, including 2-D images as well as datacubes of three or more dimensions. SIA data discovery is based on the ObsCore Data Model (ObsCoreDM), which primarily describes data products by the physical axes (spatial, spectral, time, and polarization) [10].

The resource described through the created ObsCore table can thus also be used as the basis for a SIA compliant service interface, temporarily hosted at `http://archives.ia2.inaf.it/ivoa/siapv2/lbt/query?` .

The SIA service can be explored by the client Aladin as shown in this section. After having launched it: Aladin → File → Open server selector → VO → Generic Simple Image Access v2 query → fill the "Target field" and put the URL above in the field "Server IVOID or base URL" → SUBMIT

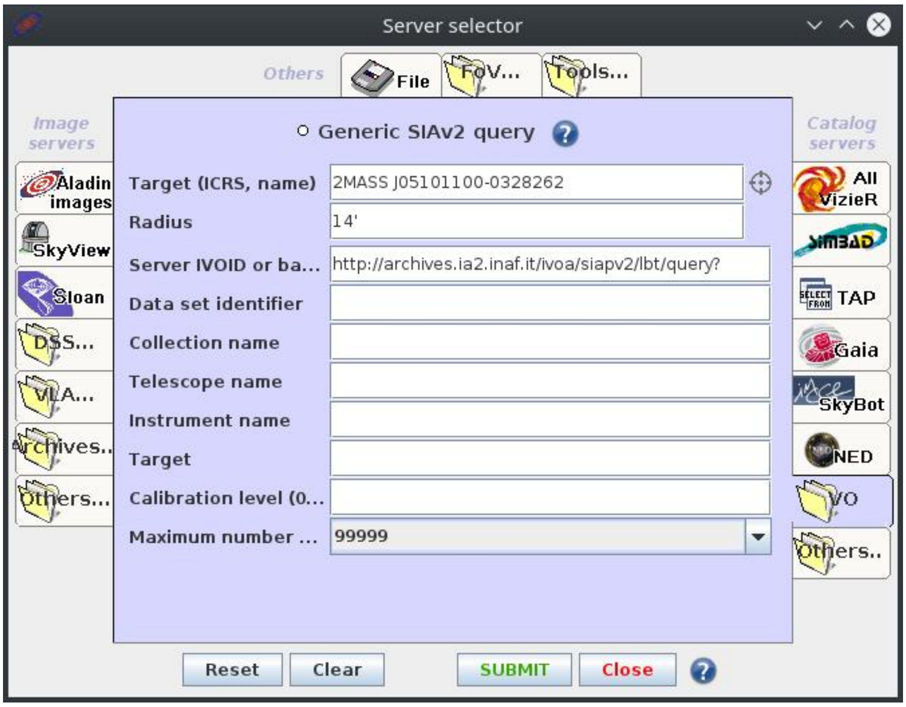

Figure 2:

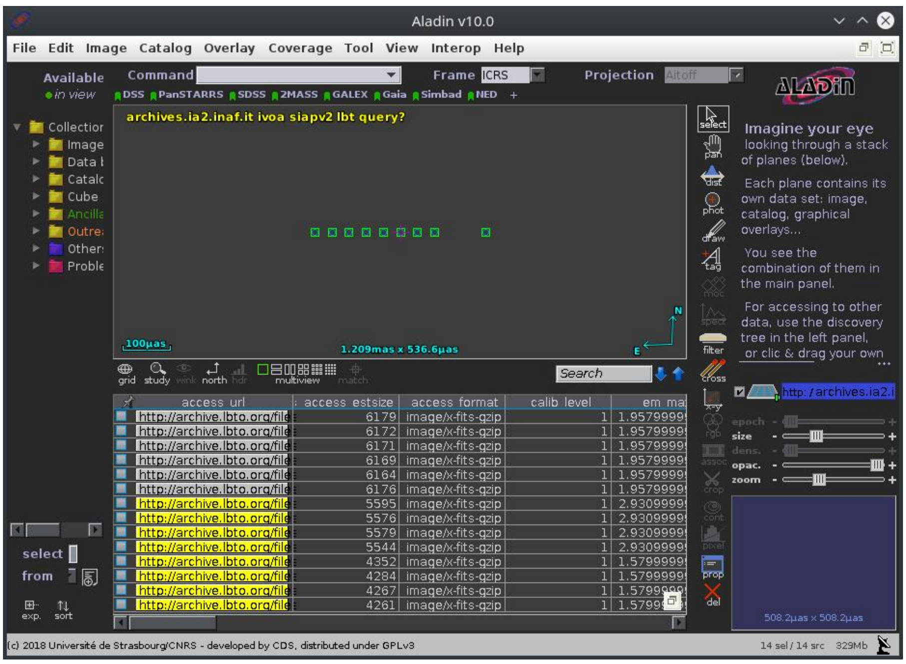

Figure 3: In this picture the ObsCore table is shown. The links to the images are colored in grey while the spectra ones are highlighted in yellow. The green small boxes in the preview window show the footprints in the sky.

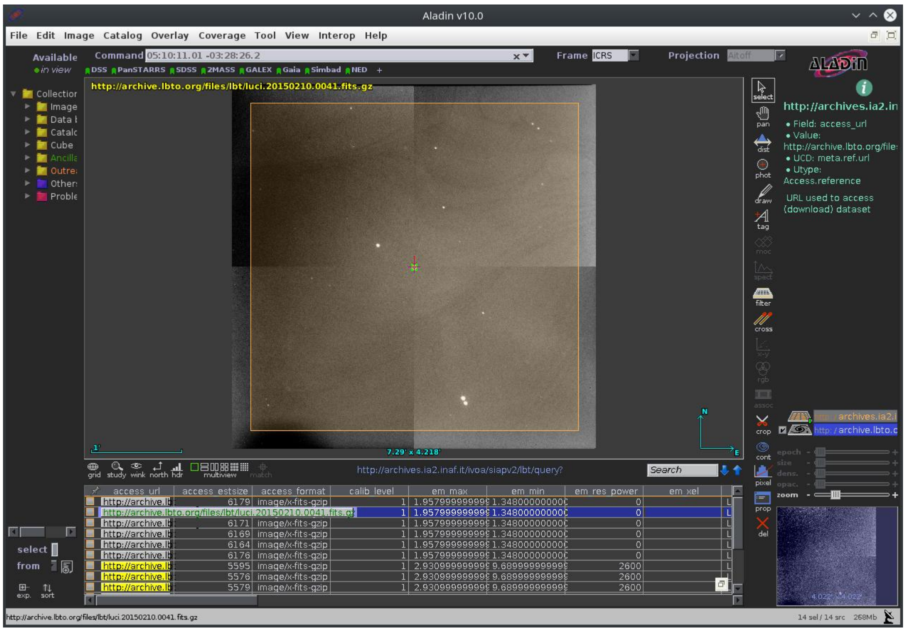

Figure 4: Here a preview of an image is shown. The orange box superimposed on the image is the representation of the s_region field of the ObsCore table

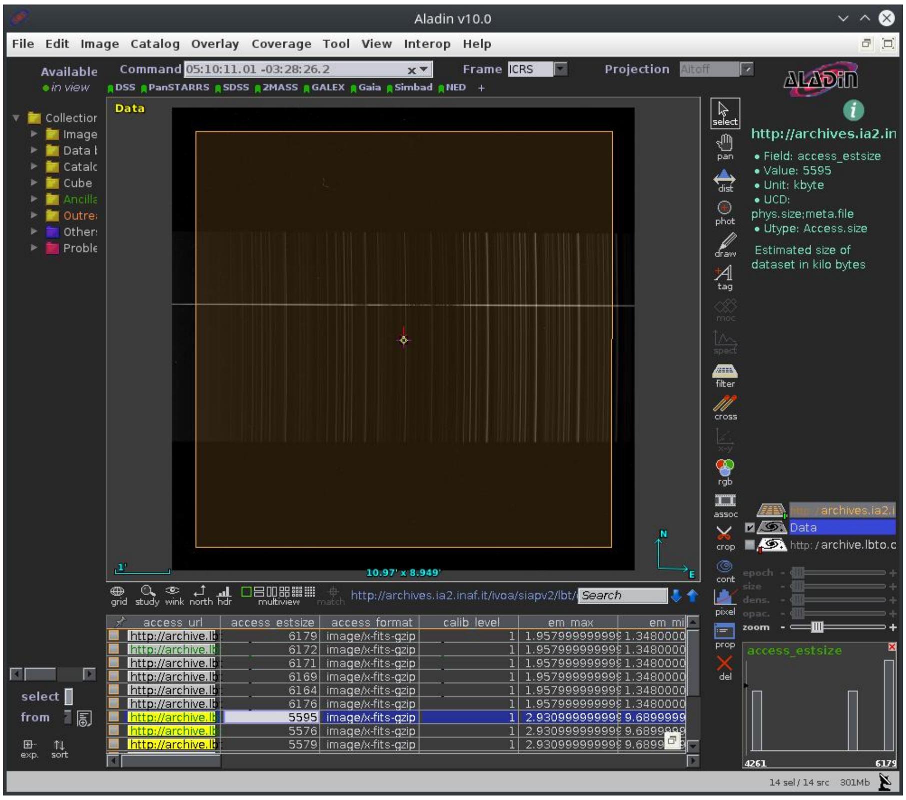

Figure 5: Same as the previous picture but for a spectrum.

8 Conclusions

The aim of this report is mainly to draw a possible, though arduous, strategy to collect the common metadata describing actual good raw data from a bigger collection of files. The final goal is to expose those raw observational datasets (grouped as collections) through interoperable discovery and access services using standard VO technologies.
Nevertheless, it is utterly important to highlight that the quality of this process, achieved through the analysis of the public logs of the observation activities, can not be considered at the same level as the one that can be provided by the scientists who actually performed the observations and/or reduced the raw data.
Moreover the "human" parsing of the logs comes at a high price in terms of both manpower and time dedicated resources. These could be quantified in 3.5 full-time months for 2.5 years of night logs (or about 1.5 PM per year) for only 1 partner, comprehensive of the time necessary to:

- understand the "logic" behind the observational strategy adopted (especially for a non-observative researcher starting from scratch);
- discriminating the status of short and long term programs progresses;
- keeping track of the actual calibrations related to each target (literally reading one week of logs at the same time if calibrations and science frames are acquired in different days).

Whereas this work can, in principle, help in boosting the visibility and FAIR-ness of the LBT science production, it can not be exploited only by hand by few persons as described in this document.
It is therefore recommended an agreement with the data provider to smooth out the process for acquiring and ingesting the ancillary informations here described, both in terms of the type of information needed and the technical solutions required. A suggestion could be that of finding a validated format (data domains and content) of the night logs making them parsable and then cross-checking their contents with the current metadata in archive. This will lead, finally, to a simple selection for identifying the desired files.

A Appendix A

Here are reported all the calibrations and acquisition files related to the proper scientific data used as a prototype for the ObsCore table described in sect. 4.

```
mysql> select distinct program_tag,piname,object,objname,imagetype,obstype,date_obs
-> from luci_publication where program='PIname 1'
-> group by program_tag,piname,object,objname,imagetype,obstype order by program asc, date_obs asc;
+------------+----------+-------------+------------------------+--------------+----------+-------------------------+
| program_tag| piname   | object      | objname                | imagetype    | obstype  | date_obs
↪ |
+------------+----------+-------------+------------------------+--------------+----------+-------------------------+
| PIname 1 A | PIname 1 | your object | NULL                   | FLAT         | NULL     | 2015-02-10T01:18:17.1022 |
| PIname 1 A | PIname 1 | SDSS J0510  | 2MASS J05101100-0328262 | OBJECT       | IMAGE    | 2015-02-10T02:26:43.8147 |
| PIname 1 A | PIname 1 | SDSS J0510  | 2MASS J05101100-0328262 | ACQUISITION  | NULL     | 2015-02-10T02:36:17.8256 |
| PIname 1 A | PIname 1 | SDSS J0510  | 2MASS J05101100-0328262 | OBJECT       | SPECTRUM | 2015-02-10T02:52:39.5231 |
| PIname 1 A | PIname 1 | Hip23098    | NULL                   | STANDARD STAR | NULL    | 2015-02-10T03:35:40.8054 |
| PIname 1 A | PIname 1 | NOTSPECIFIED | NULL                  | DARK         | NULL     | 2015-02-12T05:31:27.5150 |
| PIname 1 A | PIname 1 | NOTSPECIFIED | NULL                  | LAMP         | NULL     | 2015-02-12T08:37:42.6687 |
| PIname 1 A | PIname 1 | NOTSPECIFIED | NULL                  | FLAT         | NULL     | 2015-02-12T08:37:55.1345 |
+------------+----------+-------------+------------------------+--------------+----------+-------------------------+
```

The field program_tag[1] is just an internal tag used to create a nominal link among scientific data and their calibrations. As we can see some of them, i.e. dark, flat, have been acquired two days after the actual observation.

The piname value has been anonymized in the report for privacy reasons. The value in the field objname is the corrected name of the target, it is what will appear in the ObsCore table as target_name. Fields imagetype and obstype have been corrected by hand each time to allow us to provide an easier implementation of the code generating the final ObsCore table.

B Appendix B

In this section we list the completed targets observed analysing only INAF observing nights logs[2] from the second semester of 2014 until December 2016.

- LBT/LUCI: 50 entries that can be "safely" published.

```
mysql> select distinct program_tag,piname,object,objname,imagetype,obstype,substring(date_obs,1,10) as date_obs
    -> from luci_publication where imagetype='object'
    -> group by program_tag,piname,object,objname,imagetype,obstype order by program_tag asc, date_obs asc;
+--------------------+-----------+---------------------+-------------------------+-----------+----------+------------+
| program_tag        | piname    | object              | objname                 | imagetype | obstype  | date_obs
↪ |
+--------------------+-----------+---------------------+-------------------------+-----------+----------+------------+
| PIname 1  A        | PIname 1  | SDSS J0510          | 2MASS J05101100-0328262 | OBJECT    | IMAGE    | 2015-02-10 |
| PIname 1  A        | PIname 1  | SDSS J0510          | 2MASS J05101100-0328262 | OBJECT    | SPECTRUM | 2015-02-10 |
| PIname 1  B        | PIname 1  |                     | V* V1118 Ori            | OBJECT    | SPECTRUM | 2016-12-06 |
| PIname 1  C        | PIname 1  |                     | V* PV Cep               | OBJECT    | SPECTRUM | 2016-12-08 |
| PIname 1  C        | PIname 1  |                     | V* PV Cep               | OBJECT    | IMAGE    | 2016-12-08 |
| PIname 1  D        | PIname 1  | UZ_Tau_E            | UZ Tau E                | OBJECT    | SPECTRUM | 2016-01-25 |
| PIname 1  D        | PIname 1  | UZ_Tau_E            | UZ Tau E                | OBJECT    | IMAGE    | 2016-01-25 |
| PIname 1  E        | PIname 1  | V1118_Ori           | V* V1118 Ori            | OBJECT    | IMAGE    | 2016-01-25 |
| PIname 1  E        | PIname 1  | V1118_Ori           | V* V1118 Ori            | OBJECT    | SPECTRUM | 2016-01-25 |
| PIname 1  F        | PIname 1  | V1647_Ori           | V* V1647 Ori            | OBJECT    | IMAGE    | 2016-01-25 |
| PIname 1  F        | PIname 1  | V1647_Ori           | V* V1647 Ori            | OBJECT    | SPECTRUM | 2016-01-25 |
| PIname 1  G        | PIname 1  | V1118_Ori           | V* V1118 Ori            | OBJECT    | SPECTRUM | 2016-03-02 |
| PIname 1  H        | PIname 1  | DR_Tau              | V* DR Tau               | OBJECT    | IMAGE    | 2016-03-04 |
| PIname 1  H        | PIname 1  | DR_Tau              | V* DR Tau               | OBJECT    | SPECTRUM | 2016-03-04 |
| PIname 1  I        | PIname 1  | VY_Tau              | V* VY Tau               | OBJECT    | SPECTRUM | 2016-03-04 |
```

[1] We created other tables to store all the informations we need to publish raw data.

[2] To be safe against different proprietary period of raw data of the others partner for observations in the past (earlier than the end of 2018).

PIname 1 I	PIname 1	VY_Tau	V* VY Tau	OBJECT	IMAGE	2016-03-04
PIname 1 L	PIname 1		V* V2492 Cyg	OBJECT	SPECTRUM	2016-11-08
PIname 2 A4-H2	PIname 2	G24.78+0.08	GAL 024.78+00.08	OBJECT	IMAGE	2016-05-03
PIname 2 A4-Ks	PIname 2	G24.78+0.08	GAL 024.78+00.08	OBJECT	IMAGE	2016-05-03
PIname 2 A5-H2	PIname 2	G28.87+0.07	GAL 028.86-00.07	OBJECT	IMAGE	2016-05-05
PIname 2 A5-Ks	PIname 2	G28.87+0.07	GAL 028.86-00.07	OBJECT	IMAGE	2016-05-05
PIname 3	PIname 3	DSF2237b_Cresci	DSF2237b	OBJECT	IMAGE	2014-10-30
PIname 4 E	PIname 4	2XMMJ123204.9+215254	2XMMJ123204.9+215254	OBJECT	SPECTRUM	2015-04-29
PIname 4 F	PIname 4	2XMMJ135055.7+642857	2XMMJ135055.7+642857	OBJECT	SPECTRUM	2015-04-28
PIname 4 G	PIname 4	2XMMJ143623.8+631726	2XMMJ143623.8+631726	OBJECT	SPECTRUM	2015-04-28
PIname 5 A1	PIname 5	ID3605	NULL	OBJECT	SPECTRUM	2015-12-01
PIname 5 A2	PIname 5	ID3605	NULL	OBJECT	SPECTRUM	2016-01-25
PIname 5 A3	PIname 5	ID3605	NULL	OBJECT	SPECTRUM	2016-01-28
PIname 5 A4	PIname 5	ID3605	NULL	OBJECT	SPECTRUM	2016-01-29
PIname 6 A1-Br_Gam	PIname 6	M0717	MACS J0717.5+3745	OBJECT	IMAGE	2015-11-29
PIname 6 A1-Br_Gam	PIname 6	M0717	MACS J0717.5+3745	OBJECT	IMAGE	2015-12-02
PIname 6 A1-H2	PIname 6	M0717	MACS J0717.5+3745	OBJECT	IMAGE	2015-11-25
PIname 6 A1-H2	PIname 6	M0717	MACS J0717.5+3745	OBJECT	IMAGE	2015-12-02
PIname 6 A2-Br_Gam	PIname 6	M0717	MACS J0717.5+3745	OBJECT	IMAGE	2016-01-25
PIname 6 A2-H2	PIname 6	M0717	MACS J0717.5+3745	OBJECT	IMAGE	2016-01-26
PIname 7 A1	PIname 7	0745+4734	QSO J0745+4734	OBJECT	SPECTRUM	2015-02-11
PIname 7 A2	PIname 7	0801+5210	NULL	OBJECT	SPECTRUM	2015-02-11
PIname 7 A3	PIname 7	0900+4215	QSO J0900+4215	OBJECT	SPECTRUM	2015-02-11
PIname 7 A4	PIname 7	0958+2827	2MASS J09584122+2827291	OBJECT	SPECTRUM	2015-03-22
PIname 7 A5	PIname 7	1201+0116	QSO J1201+0116	OBJECT	SPECTRUM	2015-04-28
PIname 7 A6	PIname 7	1535+0855	QSO J1538+0855	OBJECT	SPECTRUM	2015-04-28
PIname 7 B1-1	PIname 7	1106+6400	SDSS J110610.71+640010.0	OBJECT	SPECTRUM	2015-03-23
PIname 7 B1-2	PIname 7	1106+6400	SDSS J110610.71+640010.0	OBJECT	SPECTRUM	2015-04-28
PIname 7 B3	PIname 7	2123-0050	QSO 2123-0050	OBJECT	SPECTRUM	2015-06-22
PIname 8 DDT	PIname 8	LH_USS1	[MPN2016] LH4721	OBJECT	SPECTRUM	2016-03-04
PIname 9 A2	PIname 9		NGC 2712	OBJECT	SPECTRUM	2016-12-08
PIname 9 B1	PIname 9		2MASX J00040192+7019185	OBJECT	SPECTRUM	2016-11-08
PIname 9 B2	PIname 9		Cyg A	OBJECT	SPECTRUM	2016-11-07
PIname 10 Too	PIname 10	GRB151027A	GRB 151027A	OBJECT	IMAGE	2015-11-30
PIname 10 Too	PIname 10	darkgrb	GRB 151027A	OBJECT	IMAGE	2015-11-30

The field date_obs (here is reported the date only for printing purpose) indicates the day in which each subset of observations has been acquired.

- LBT/MODS: 76 entries.

```
mysql> select distinct program_tag,piname,object,objname,imagetyp,obs_type,substring(date_obs,1,10) as date_obs
    -> from mods_publication where imagetyp='object' and object not like '% Acquisition'
    -> group by program_tag,piname,object,objname,imagetyp,obs_type order by program_tag asc, date_obs asc;
```

program_tag	piname	object	objname	imagetyp	obs_type	date_obs
PIname 1 A	PIname 1	DDO68 runb	UGC 5340	OBJECT	SPECTRUM	2016-12-06
PIname 2 B	PIname 2	v1143 Ori	V* V1143 Ori	OBJECT	IMAGE	2014-12-21
PIname 2 C	PIname 2	VY Tau	V* VY Tau	OBJECT	SPECTRUM	2014-12-21
PIname 2 D	PIname 2	VY Tau	V* VY Tau	OBJECT	IMAGE	2014-12-21
PIname 2 E	PIname 2	SDSSJ0510	SDSS J051011.01-032826.2	OBJECT	SPECTRUM	2014-12-21
PIname 2 F	PIname 2	SDSSJ0510	SDSS J051011.01-032826.2	OBJECT	IMAGE	2014-12-21
PIname 2 G	PIname 2	XZ Tau	V* XZ Tau	OBJECT	SPECTRUM	2014-12-21
PIname 2 H	PIname 2	XZ Tau	V* XZ Tau	OBJECT	IMAGE	2014-12-21
PIname 2 I	PIname 2	NY Ori	V* NY Ori	OBJECT	SPECTRUM	2014-12-21
PIname 2 L	PIname 2	NY Ori	V* NY Ori	OBJECT	IMAGE	2014-12-21
PIname 2 M	PIname 2	v1143 Ori	V* V1143 Ori	OBJECT	SPECTRUM	2014-12-21
PIname 2 N	PIname 2	UZ Tau E	UZ Tau E	OBJECT	SPECTRUM	2014-12-22
PIname 2 O	PIname 2	V1118 Ori	V* V1118 Ori	OBJECT	SPECTRUM	2014-12-22
PIname 2 P	PIname 2	V1184 Tau	V* V1184 Tau	OBJECT	SPECTRUM	2014-12-22
PIname 2 Q	PIname 2	V1184 Tau	V* V1184 Tau	OBJECT	IMAGE	2014-12-22
PIname 2 R1	PIname 2	v2492 Cyg	V* V2492 Cyg	OBJECT	IMAGE	2015-06-24
PIname 2 R2	PIname 2	v2492 Cyg	V* V2492 Cyg	OBJECT	SPECTRUM	2015-06-24
PIname 2 R3	PIname 2	v2493 Cyg	V* V2493 Cyg	OBJECT	IMAGE	2015-06-24
PIname 2 R4	PIname 2	v2493 Cyg	V* V2493 Cyg	OBJECT	SPECTRUM	2015-06-24
PIname 2 R5	PIname 2	PV Cep	V* PV Cep	OBJECT	IMAGE	2015-06-24
PIname 2 R6	PIname 2	PV Cep	V* PV Cep	OBJECT	SPECTRUM	2015-06-24
PIname 2 S1	PIname 2	V1118 Ori	V* V1118 Ori	OBJECT	SPECTRUM	2015-10-01
PIname 2 S2	PIname 2	SDSSJ0510	SDSS J051011.01-032826.2	OBJECT	IMAGE	2015-10-01
PIname 2 S3	PIname 2	SDSSJ0510	SDSS J051011.01-032826.2	OBJECT	SPECTRUM	2015-10-01
PIname 2 S4	PIname 2	V512 Per	V* V512 Per	OBJECT	IMAGE	2015-10-01
PIname 2 S5	PIname 2	V512 Per	V* V512 Per	OBJECT	SPECTRUM	2015-10-01
PIname 2 S6	PIname 2	V1118 Ori	V* V1118 Ori	OBJECT	IMAGE	2015-10-01
PIname 2 T	PIname 2	V1118 Ori	V* V1118 Ori	OBJECT	SPECTRUM	2016-01-12
PIname 2 U1	PIname 2	V1118 Ori	V* V1118 Ori	OBJECT	SPECTRUM	2016-12-04
PIname 2 U2	PIname 2	V1118 Ori	V* V1118 Ori	OBJECT	IMAGE	2016-12-04
PIname 3 DDT1	PIname 3	SECCO_C1	[RDS2004] MGS sure 21	OBJECT	SPECTRUM	2016-03-03
PIname 3 DDT2	PIname 3	SECCO_C2	APMUKS (BJ) B114159.94-003523.7	OBJECT	SPECTRUM	2016-03-03
PIname 4 B	PIname 4	2XMMJ135055.7+642857	2XMM J135055.7+642857	OBJECT	SPECTRUM	2016-07-03
PIname 4 A	PIname 4	2XMMJ100038.9+050955	2XMMJ100038.9+050955	OBJECT	SPECTRUM	2014-12-21
PIname 5 A	PIname 5	Fiore GOODS-North Field 1	GOODS-North Field	OBJECT	SPECTRUM	2015-03-21
PIname 6 L	PIname 6	P04	PA-4	OBJECT	SPECTRUM	2014-09-20
PIname 6 M	PIname 6	P09	PA-9	OBJECT	SPECTRUM	2014-09-20
PIname 6 N	PIname 6	P46	PA-46	OBJECT	SPECTRUM	2014-09-20
PIname 6 O	PIname 6	MCGC9	[HTF2008] H24	OBJECT	SPECTRUM	2014-09-21
PIname 6 P	PIname 6	MCGC8	[HTF2008] H23	OBJECT	SPECTRUM	2014-09-20
PIname 6 Q	PIname 6	B517	Bol 517	OBJECT	SPECTRUM	2014-10-28
PIname 6 R	PIname 6	H2	[HTF2008] H2	OBJECT	SPECTRUM	2014-10-28
PIname 6 S	PIname 6	H7	[HTF2008] H7	OBJECT	SPECTRUM	2014-10-29
PIname 6 T	PIname 6	G002	Mayall II	OBJECT	SPECTRUM	2014-10-29
PIname 7 VF1	PIname 7	Giallongo VIRGO Point 1	VIRGO CLUSTER	OBJECT	SPECTRUM	2016-05-03
PIname 7 VF2	PIname 7	Giallongo VIRGO Point 2	VIRGO CLUSTER	OBJECT	SPECTRUM	2016-05-03
PIname 8 A	PIname 8	Grazian SDSS36 Point 1	SDSS J014757.45+273326.7	OBJECT	SPECTRUM	2016-11-05
PIname 9 A1	PIname 9	CATSJ021950	CATSJ021950	OBJECT	SPECTRUM	2015-02-13
PIname 9 A4	PIname 9	CXOUJ204734	CXOUJ204734	OBJECT	SPECTRUM	2015-06-22
PIname 9 A5	PIname 9	CXOUJ215447	CXOUJ215447	OBJECT	SPECTRUM	2015-06-23
PIname 9 A6	PIname 9	CXOUJ215544	CXOUJ215544	OBJECT	SPECTRUM	2015-06-20
PIname 9 A7	PIname 9	CATSJ193437	CXO j193437.8+302524	OBJECT	SPECTRUM	2015-06-21
PIname 10 M12	PIname 10	Messier 12	M 12	OBJECT	SPECTRUM	2015-06-20
PIname 10 M15	PIname 10	M 15	M 15	OBJECT	SPECTRUM	2015-06-25
PIname 10 M71	PIname 10	M 71	M 71	OBJECT	SPECTRUM	2015-06-22
PIname 11 A	PIname 11	3FGL_J0258.2+3555	3FGL J0258.2+3555	OBJECT	SPECTRUM	2016-12-07
PIname 12 MOS 20 A	PIname 12	SDSSJ1411 M20	SDSS J141111.27+121737.3	OBJECT	SPECTRUM	2015-02-13
PIname 12 MOS 20 B	PIname 12	SDSSJ1411 M20	SDSS J141111.27+121737.3	OBJECT	SPECTRUM	2015-03-22

```
| PIname 12 MOS 21 A | PIname 12 | SDSSJ1411 M21            | SDSS J141111.27+121737.3      | OBJECT   | SPECTRUM | 2015-03-23 |
| PIname 12 MOS 21 B | PIname 12 | SDSSJ1411 M21            | SDSS J141111.27+121737.3      | OBJECT   | SPECTRUM | 2015-06-21 |
| PIname 12 MOS 21 B | PIname 12 | SDSSJ1411 M21            | SDSS J141111.27+121737.3      | OBJECT   | SPECTRUM | 2015-06-22 |
| PIname 12 MOS 22 A | PIname 12 | SDSSJ1148 M22            | SDSS J114816.64+525150.3      | OBJECT   | SPECTRUM | 2015-01-15 |
| PIname 12 MOS 22 B | PIname 12 | SDSSJ1148 M22            | SDSS J114816.64+525150.3      | OBJECT   | SPECTRUM | 2015-02-11 |
| PIname 13 GJ       | PIname 13 | GJ3470b                  | GJ 3470 b                     | OBJECT   | SPECTRUM | 2016-01-14 |
| PIname 13 HAT-32   | PIname 13 | HAT-32                   | HAT-32                        | OBJECT   | SPECTRUM | 2014-10-31 |
| PIname 13 WASP-52  | PIname 13 | WASP-52                  | WASP-52                       | OBJECT   | SPECTRUM | 2015-10-01 |
| PIname 14 A17      | PIname 14 | MCGC8-H23                | [HTF2008] H23                 | OBJECT   | SPECTRUM | 2016-11-05 |
| PIname 14 A5       | PIname 14 | PAndAS-17                | PAndAS-17                     | OBJECT   | SPCETRUM | 2016-11-05 |
| PIname 14 H12      | PIname 14 | H12                      | [HTF2008] H12                 | OBJECT   | SPECTRUM | 2016-12-07 |
| PIname 14 H18      | PIname 14 | H18                      | [HTF2008] H18                 | OBJECT   | SPECTRUM | 2016-12-07 |
| PIname 15 B        | PIname 15 | RDCS mask 1              | RDCS J0848+4453               | OBJECT   | SPECTRUM | 2015-02-13 |
| PIname 15 F        | PIname 15 | XLSS_mask1               | XLSS J022303.3-043621         | OBJECT   | SPECTRUM | 2014-10-28 |
| PIname 15 V        | PIname 15 | M003XLSms1               | XLSS J022303.3-043621         | OBJECT   | SPECTRUM | 2015-11-07 |
| PIname 15 W1       | PIname 15 | M004XLSms2               | XLSS J022303.3-043621         | OBJECT   | SPECTRUM | 2015-11-09 |
| PIname 15 W2       | PIname 15 | M004XLSms2               | M004XLSms2                    | OBJECT   | SPECTRUM | 2016-01-12 |
| PIname 15 Z        | PIname 15 | M003XLSms1               | XLSS J022303.3-043621         | OBJECT   | SPECTRUM | 2015-10-02 |
| PIname 16 A        | PIname 16 | M024ngc4535              | NGC 4535                      | OBJECT   | SPECTRUM | 2015-02-11 |
| PIname 17 A        | PIname 17 | J1935+1726               | PSR J1935+1726                | OBJECT   | SPECTRUM | 2016-07-03 |
+--------------------+-----------+--------------------------+-------------------------------+----------+----------+------------+
```

- LBT/LBC: 81 entries.

```
mysql> select distinct program_tag,piname,object,objname,obs_type,substring(date_obs,1,10) as date_obs
    -> from lbc_publication where obs_type='object'
    -> group by program_tag,piname,object,objname,obs_type order by program_tag asc, date_obs asc;
+--------------------+----------+--------------+----------------------------------+----------+------------+
| program_tag        | piname   | object       | objname                          | obs_type | date_obs
↪ |
+--------------------+----------+--------------+----------------------------------+----------+------------+
| PIname 1           | PIname 1 | DDO68        | UGC 5340                         | object   | 2016-01-12 |
| PIname 1 R1        | PIname 1 | UGC685       | UGC 685                          | object   | 2016-11-05 |
| PIname 1 R10       | PIname 1 | UGC3974      | UGC 3974                         | object   | 2016-11-07 |
| PIname 1 R2        | PIname 1 | UGC1249      | UGC 1249                         | object   | 2016-11-06 |
| PIname 1 R3        | PIname 1 | UGC1281      | UGC 1281                         | object   | 2016-11-07 |
| PIname 1 R8        | PIname 1 | UGC3755      | UGC 3755                         | object   | 2016-11-05 |
| PIname 2           | PIname 2 | IGR J00291+59 | IGR J00291+5934                 | object   | 2016-11-06 |
| PIname 3 A2        | PIname 3 | 063.7+33.3   | [DPP2015] 3                      | object   | 2015-11-07 |
| PIname 3 B2        | PIname 3 | 084.4+24.0   | [SPG2012] 084.4+24.0+152         | object   | 2015-11-07 |
| PIname 3 C         | PIname 3 | 086.4+31.8   | [SPG2012] 086.4+31.8+612         | object   | 2016-01-12 |
| PIname 3 C1        | PIname 3 | 086.4+31.8   | [SPG2012] 086.4+31.8+612         | object   | 2016-11-05 |
| PIname 3 C2        | PIname 3 | 086.4+31.8   | [SPG2012] 086.4+31.8+612         | object   | 2015-11-07 |
| PIname 3 D         | PIname 3 | 090.9+30.9   | [SPG2012] 090.9+30.9+266         | object   | 2016-01-13 |
| PIname 3 D2        | PIname 3 | 090.9+30.9   | [SPG2012] 090.9+30.9+266         | object   | 2015-11-07 |
| PIname 3 DDT1      | PIname 3 | SECCO_C1     | [RDS2004] MGS sure 21            | object   | 2016-03-03 |
| PIname 3 DDT2      | PIname 3 | SECCO_C2     | APMUKS (BJ) B114159.94-003523.7  | object   | 2016-03-03 |
| PIname 3 E2        | PIname 3 | 092.1+09.5   | [SPG2012] 092.1+09.5+584         | object   | 2015-11-07 |
| PIname 3 F2        | PIname 3 | 100.0+36.7   | [SPG2012] 100.0+36.7+417         | object   | 2015-11-07 |
| PIname 3 G2        | PIname 3 | 100.9+09.2   | [SPG2012] 100.9+09.2+311         | object   | 2015-11-07 |
| PIname 3 H         | PIname 3 | 104.4+04.1   | [SPG2012] 104.4+04.1-145         | object   | 2015-11-08 |
| PIname 3 I         | PIname 3 | 143.7+12.9   | [SPG2012] 143.7+12.9+223         | object   | 2016-01-12 |
| PIname 3 I2        | PIname 3 | 143.7+12.9   | [SPG2012] 143.7+12.9+223         | object   | 2016-12-05 |
| PIname 3 J         | PIname 3 | 147.0+07.1   | [SPG2012] 147.0+07.1+525         | object   | 2016-01-12 |
| PIname 3 J2        | PIname 3 | 147.0+07.1   | [SPG2012] 147.0+07.1+525         | object   | 2016-12-05 |
| PIname 3 K         | PIname 3 | 183.0+04.4   | [SPG2012] 183.0+04.4-112         | object   | 2016-01-12 |
| PIname 3 L         | PIname 3 | 195.9+06.9   | [SPG2012] 195.9+06.9-100         | object   | 2016-01-12 |
| PIname 3 M         | PIname 3 | 196.6+06.5   | [DPP2015] 11                     | object   | 2016-01-12 |
| PIname 3 N1        | PIname 3 | 331.8+21.0   | [SPG2012] 331.8+21.0+303         | object   | 2015-10-02 |
| PIname 3 O1        | PIname 3 | 339.0+09.0   | [SPG2012] 339.0+09.0-237         | object   | 2015-10-02 |
| PIname 3 O2        | PIname 3 | 339.0+09.0   | [SPG2012] 339.0+09.0-237         | object   | 2015-11-07 |
| PIname 3 P1        | PIname 3 | 341.7+07.7   | [DPP2015] 14                     | object   | 2015-10-02 |
| PIname 3 P2        | PIname 3 | 341.7+07.7   | [DPP2015] 14                     | object   | 2015-11-07 |
| PIname 3 Q1        | PIname 3 | 342.1+20.6   | [SPG2012] 342.1+20.6+208         | object   | 2015-10-02 |
| PIname 3 Q2        | PIname 3 | 342.1+20.6   | [SPG2012] 342.1+20.6+208         | object   | 2015-11-07 |
| PIname 3 R1        | PIname 3 | 345.0+07.0   | LEDA 1311801                     | object   | 2015-10-02 |
| PIname 4 A1        | PIname 4 | MACSJ0717.5  | MACS J0717.5+3745                | object   | 2015-11-08 |
```

PIname 4 A2	PIname 4	MACSJ0717.5	MACS J0717.5+3745	object	2015-11-09
PIname 4 A3	PIname 4	MACSJ0717.5	MACS J0717.5+3745	object	2016-01-13
PIname 4 A4	PIname 4	MACSJ0717.5	MACS J0717.5+3745	object	2016-02-29
PIname 4 A5	PIname 4	MACSJ0717.5	MACS J0717.5+3745	object	2016-03-03
PIname 4 A6	PIname 4	MACSJ0717.5	MACS J0717.5+3745	object	2016-11-05
PIname 5 P1	PIname 5	Pegasus_III	Pegasus III	object	2015-10-02
PIname 5 P1	PIname 5	Pisces_II	Pisces II	object	2015-10-02
PIname 5 P2	PIname 5	Pegasus_III	Pegasus III	object	2015-11-07
PIname 5 P2	PIname 5	Pisces_II	Pisces II	object	2015-11-07
PIname 5 P3	PIname 5	Pegasus_III	Pegasus III	object	2015-11-09
PIname 5 P3	PIname 5	Pisces_II	Pisces II	object	2015-11-09
PIname 5 P4	PIname 5	Pegasus_III	Pegasus III	object	2015-12-01
PIname 5 P4	PIname 5	Pisces_II	Pisces II	object	2015-12-01
PIname 6 A	PIname 6	N188	NGC 188	object	2015-11-30
PIname 6 B	PIname 6	Tr5	NULL	object	2016-01-13
PIname 7 B	PIname 7	2014KC46	2014 KC46	object	2014-10-28
PIname 7 A	PIname 7	426071	NULL	object	2016-03-01
PIname 7 A	PIname 7	267221	NULL	object	2016-03-01
PIname 7 A	PIname 7	2007VA85	NULL	object	2016-03-01
PIname 7 A	PIname 7	313276	NULL	object	2016-03-01
PIname 8 A	PIname 8	GOODS-NORTH	GOODS-North Field	object	2015-03-21
PIname 9 VF1	PIname 9	VIRGO	VIRGO CLUSTER	object	2016-05-03
PIname 9 VF2	PIname 9	VIRGO	VIRGO CLUSTER	object	2016-05-03
PIname 10 A3	PIname 10	J1148+52	NULL	object	2016-01-28
PIname 11 A1	PIname 11	IZw18	I Zw 18	object	2016-01-12
PIname 11 A2	PIname 11	IZw18	I Zw 18	object	2016-01-27
PIname 11 A3	PIname 11	IZw18	I Zw 18	object	2016-02-29
PIname 11 A4	PIname 11	IZw18	I Zw 18	object	2016-03-02
PIname 12	PIname 12	J2043+2740	PSR J2043+2740	object	2016-07-04
PIname 13 MOS 20-1	PIname 13	J1411+12	NULL	object	2015-02-13
PIname 13 MOS 20-2	PIname 13	J1411+12	NULL	object	2015-02-14
PIname 13 MOS 20-3	PIname 13	J1411+12	NULL	object	2015-03-22
PIname 13 MOS 21-1	PIname 13	J1411+12	NULL	object	2015-03-23
PIname 13 MOS 21-2	PIname 13	J1411+12	NULL	object	2015-06-21
PIname 13 MOS 21-3	PIname 13	J1411+12	NULL	object	2015-06-22
PIname 13 MOS 22-1	PIname 13	J1148+52	NULL	object	2015-01-15
PIname 13 MOS 22-2	PIname 13	J1148+52	NULL	object	2015-01-16
PIname 13 MOS 22-3	PIname 13	J1148+52	NULL	object	2015-02-10
PIname 13 MOS 22-4	PIname 13	J1148+52	NULL	object	2015-02-11
PIname 14 GJ	PIname 14	GJ3470	GJ 3470 b	object	2016-01-14
PIname 14 HAT-32	PIname 14	hat-p-32	HAT-32	object	2014-10-31
PIname 14 WASP-52	PIname 14	wasp52	WASP-52	object	2015-10-01
PIname 15 Too	PIname 15	GRB151027A	GRB 151027A	object	2015-11-30
PIname 15 Too 2	PIname 15	GRB151027A	GRB 151027A	object	2016-01-27
PIname 16 F	PIname 16	XLSSm1	XLSS J022303.3-043621	object	2014-10-29

The main difference between the LBT/LUCI ObsCore table and the analogous tables for LBT/MODS and LBT/LBC rely on the way we can compute the s_region field.

Currently, the MODS FITS headers do not provide any World Coordinate System keywords thus the safest choices to compute the s_fov and s_region fields we adopted are: s_fov is the diameter of the circumscribed circle of the field in order to take into account all the possible orientations of the instrument with respect to the telescope pointing; s_region is, as a consequence, the box circumscribed to this circle. This "conservative" choice still allows users to perform reliable positional queries.

The lack of WCS annotation in the MODS FITS header makes it impossible to client applications (like Aladin) to visualize the footprint on top of a sky reference frame. This happens because the astrometric content provided in the obscore table is part of that table and not of the dataset.

Whilst a minimal WCS keyword set can, in principle, be added to the MODS datasets to overcome this issue, we prefer not doing so. This is to avoid providing a misleading WCS content in the FITS header that would be confusing for the final users who, when accessing the dataset alone, will use a wrong astrometric calibration without being aware of it. Therefore, we strongly suggest to the data provider to deliver final raw data with the appropriate WCS keywords in them.

The single LBC camera is equipped with four science CCDs arranged in a mosaic with three of them aligned

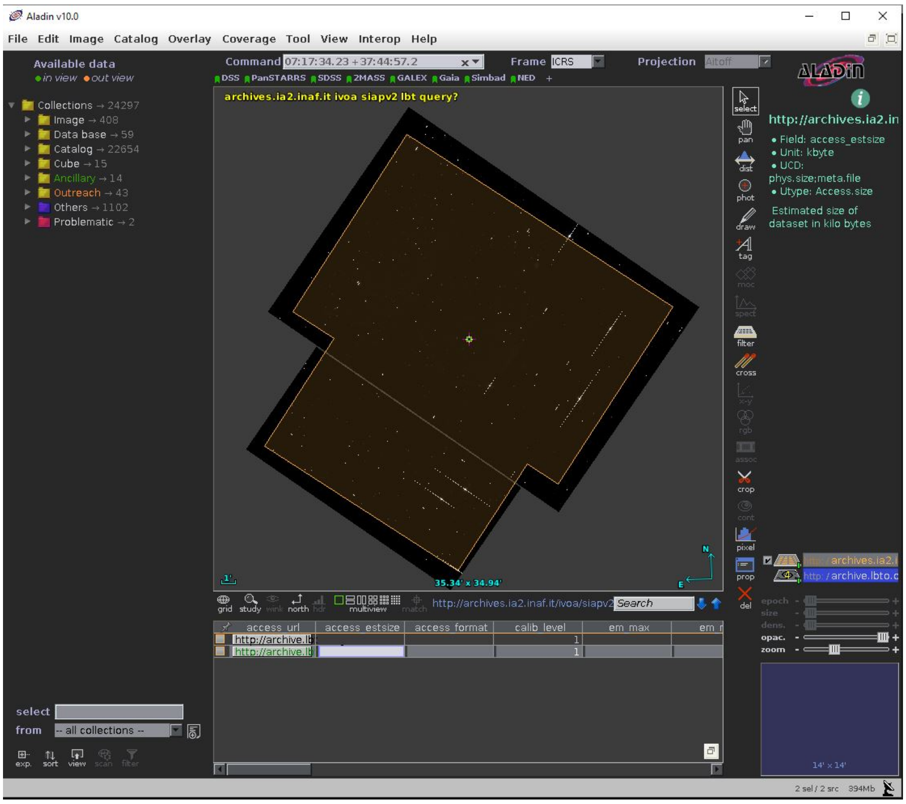

Figure 6: The proposed footprint for raw LBC images displayed in Aladin.

with each other, while the fourth CCD is rotated clockwise 90 degrees and centered along the top of the others. All the four CCDs have a gap of 70 pixels among them. A full LBC image is a mosaic of four chips stored in a multi-extension FITS, each one with its own WCS set of keywords referring to a common pointing. In this case we compute the s_region as a polygon containing the entire field of view using only the WCS of the central chip, and the s_fov as the diameter of the circle that best encompasses the s_region.