



GAPS Time Series

Resource and Service Implementation

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Outline

- GAPS Time Series
- GAPS Time Series in Virtual Observatory (VO)
- ObsTAP Service
- Next steps



The GAPS Project

GAPS (Global Architecture of Planetary Systems) is a long-term program for the comprehensive characterization of the architectural properties of planetary systems as a function of the hosts' characteristics (mass, metallicity, environment):

- more than 50 INAF and associated scientists in Italy, and from foreign institutes
- more than 15.000 spectra at TNG (HARPS-N and GIANO-B) since August 2012

GAPS required a strong interaction with TNG private data

- Customizable re-process of GAPS data with appropriate spectral line mask and options;
- Perform queries on additional metadata content;
- A flexible and collaborative tool to manage additional info about the project and the observations;
- A repository where to access, synchronize, share and search for interesting data.



GAPS Time Series

- Product of the GAPS project
- Internally stored and built
- RV temporal series

RML Time Series
M Time Series
KP Time Series
MP Time Series
OC Time Series
AST-IP-STD-GATO Time Series

GAPS KP Targets

GAPS Name	α	δ	$\mu\alpha$	$\mu\delta$	Mv	(B-V)	Spectral Type	Radial Velocity	Number of Data	Discarded Data	Time Series	Pdf Report	Status	Update On
KP1	03:48:00.370	+40:31:50.30	0.054000	0.021100	7.24	0.634	G2	-10.100	93	0	KP1.dat	KP1.pdf	active	2017-10-05 at 03:50
KP2	05:23:21.570	-02:16:39.40	0.034400	-0.096900	8.94	0.761	G5	29.590	51	0	KP2.dat	KP2.pdf	active	2017-10-05 at 04:50
KP3	08:53:50.810	+33:03:24.50	-0.095400	-0.028400	8.03	0.626	G0	21.300	96	0	KP3.dat	KP3.pdf	active	2019-01-23 at 01:25
KP4	10:18:21.290	+12:37:16.00	-0.272300	-0.039900	7.03	0.594	G0	22.600	63	0	KP4.dat	KP4.pdf	active	2017-05-21 at 21:18
KP5	12:15:06.570	-07:15:26.40	-0.249700	-0.052300	7.96	0.815	G5	20.660	47	0	KP5.dat	KP5.pdf	active	2017-06-23 at 21:14
KP6	02:34:11.046	-12:23:03.47	0.057300	-0.187700	9.85	0.000	F2	24.250	27	0	KP6.dat	KP6.pdf	rejected	2013-01-30 at 20:38
KP7	12:30:26.900	+22:52:47.30	0.127100	-0.089400	8.76	0.738	G9	-29.600	97	0	KP7.dat	KP7.pdf	active	2017-02-06 at 06:06
KP8	00:15:50.850	+01:12:00.75	0.002600	0.012500	11.30	0.476	F8	18.280	12	0	KP8.dat	KP8.pdf	active	2016-10-07 at 02:53
KP9	00:18:24.700	-15:16:02.30	0.025500	-0.026500	11.30	0.576	G0	8.460	12	0	KP9.dat	KP9.pdf	active	2016-10-07 at 00:36
KP10	00:20:40.080	+31:59:23.79	-0.004800	-0.005600	11.79	0.538	F7	-13.500	13	0	KP10.dat	KP10.pdf	active	2016-07-25 at 03:03



GAPS Time Series

Text File Format

```
# GAPS_NAME:    KP7
# ALPHA:       12:30:26.900
# DELTA:       +22:52:47.30
# PROPER MOTION (ALPHA):  0.127100
# PROPER MOTION (DELTA):  -0.089400
# MAGNITUDE:    8.76
# (B-V):       0.738
# SPECTRAL TYPE:  G9
# SPECTRAL TYPE OF THE MASK:  G2
# SYSTEMIC RV:  -29.600 [km/s]
# TIME SERIES UPDATED ON:  2017-02-06 at 06:06
```

- Custom ASCII format
- Used in internally developed libraries
- Datasets and metadata stored in RDB

```
# -----
#ID          H_BJD          C_BJD          RVC[km/s]          dRVC[m/s]          BIS_SPAN
1            2456266.7756144    2456266.7768700    -30.000592793654    0.438641811740    -0.033687885349
2            2456288.7600700    2456288.7592600    -30.002592926899    0.652667304176    -0.035340040928
3            2456297.7797343    2456297.7778000    -30.017483243655    1.021413642952    -0.038451460912
4            2456298.7464164    2456298.7447100    -30.013971322659    0.401420395594    -0.033602684455
5            2456299.6857577    2456299.6840800    -30.017148485730    0.342304763703    -0.036787794336
6            2456305.7751079    2456305.7729100    -30.019509192761    0.414129371691    -0.034515653547
7            2456324.7450514    2456324.7415500    -30.025061639205    0.904676089902    -0.038409472716
8            2456324.8134471    2456324.8099100    -30.024866267906    0.610715811992    -0.031641312430
9            2456344.6559588    2456344.6513500    -30.041959907801    0.344306618194    -0.035302283354
10           2456345.5576606    2456345.5529300    -30.045054078932    0.483426241143    -0.032098020289
11           2456362.6409069    2456362.6358500    -30.045100931374    0.363052628555    -0.037400048651
12           2456363.6494948    2456363.6445000    -30.044223978297    0.421959466464    -0.036265889749
13           2456364.6765535    2456364.6715900    -30.045960349050    0.431904482152    -0.038855300832
14           2456365.6796057    2456365.6743900    -30.047683570576    0.404503349773    -0.035468293995
15           2456366.5462550    2456366.5393300    -30.050098153026    0.809221945047    -0.032358314979
16           2456375.5578538    2456375.5522500    -30.053986167976    0.656030366888    -0.038302196119
17           2456376.5564906    2456376.5511800    -30.052118020609    0.381495874323    -0.034762268290
18           2456379.6199837    2456379.6147900    -30.055001407306    0.463575651085    -0.034606213278
19           2456380.6110450    2456380.6058800    -30.055845494098    0.663712314063    -0.036645746079
20           2456382.6569003    2456382.6517400    -30.054586051565    0.365017000690    -0.036948848003
21           2456398.5531917          NaN    -30.053622043262    0.569969166224    -0.034282347747
22           2456399.5046787    2456399.5000600    -30.049408795551    1.275193650360    -0.036938724265
23           2456404.5386094    2456404.5339500    -30.050609779089    0.567713324318    -0.033962760561
```



GAPS Time Series

GAPS Target: KP7

Last update: 2017-02-06 at UT 06:06:11

Star	Value
α	12:30:26.900
δ	+22:52:47.30
μ_α	0.1271 arcsec/yr
μ_δ	-0.089 arcsec/yr
M_v	8.8
$(B - V)$	0.7
Spectral Type	G9
Radial Velocity	-29.60 km/s
Known planets	2

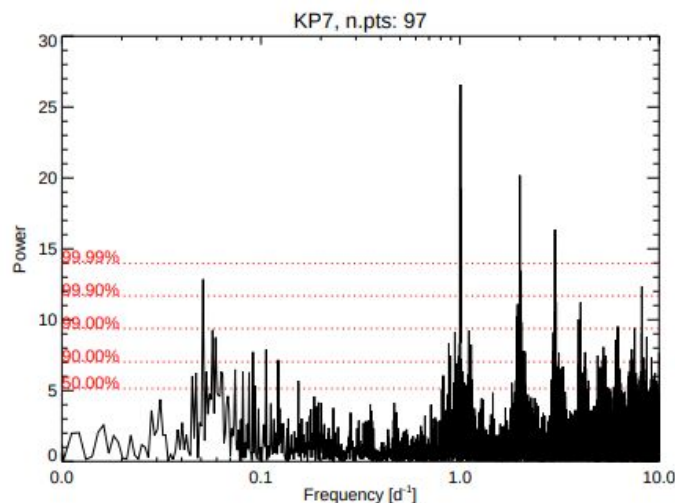
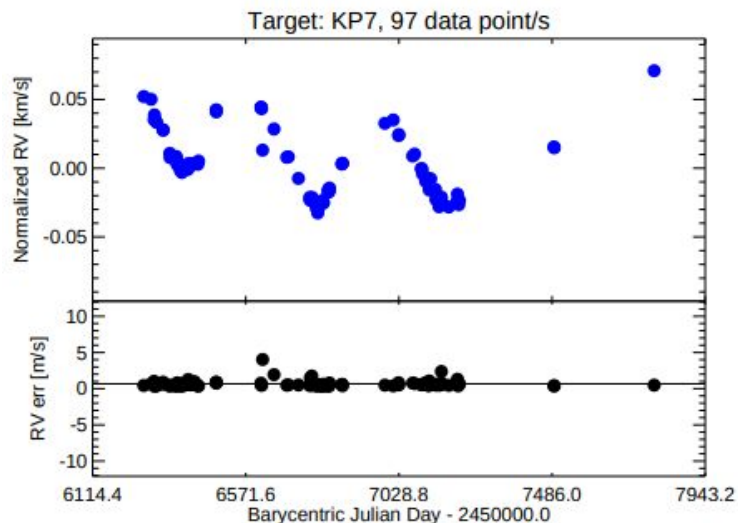
Table 1: Stellar parameters from GAPS Master Catalog.

Time series	Value
Data points	97
Acquisition	HARPN_ech_acq_wavesimult
Mean RV	-30.053 km/s
Median RV	-30.054 km/s
σ_{RV}	0.155 km/s
Mean Err_{RV}	0.66 m/s
Median Err_{RV}	0.53 m/s
$\sigma_{Err_{RV}}$	0.15 m/s
Independent frequencies ¹	118
Total SNR	10703

Table 2: Time series information. ¹From Horne & Baliunas, 1986, ApJ, 302, 757.

Pdf File Format

- Report in PDF format
- Includes global metadata and data
- Provides data overview
- Linked in the relational DB






Time Series in VO

VO & GAPS

June 2017



ASTERICS Wiki pages

Astronomy ESFRI & Research Infrastructure Cluster

Trace: • [wp4exodm](#) • [wp4](#) • [wp4gapsinaf](#)

open:wp4:wp4gapsinaf

GAPS Time Series face-to-face Meeting

INAF-OAPd, Padova, 22/06/2017

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Participants

Name	Affiliation
Marco Molinaro	INAF-OATs
Andrea Bignamini	INAF-OATs
Serena Benatti	INAF-OAPd
Riccardo Claudi	INAF-OAPd

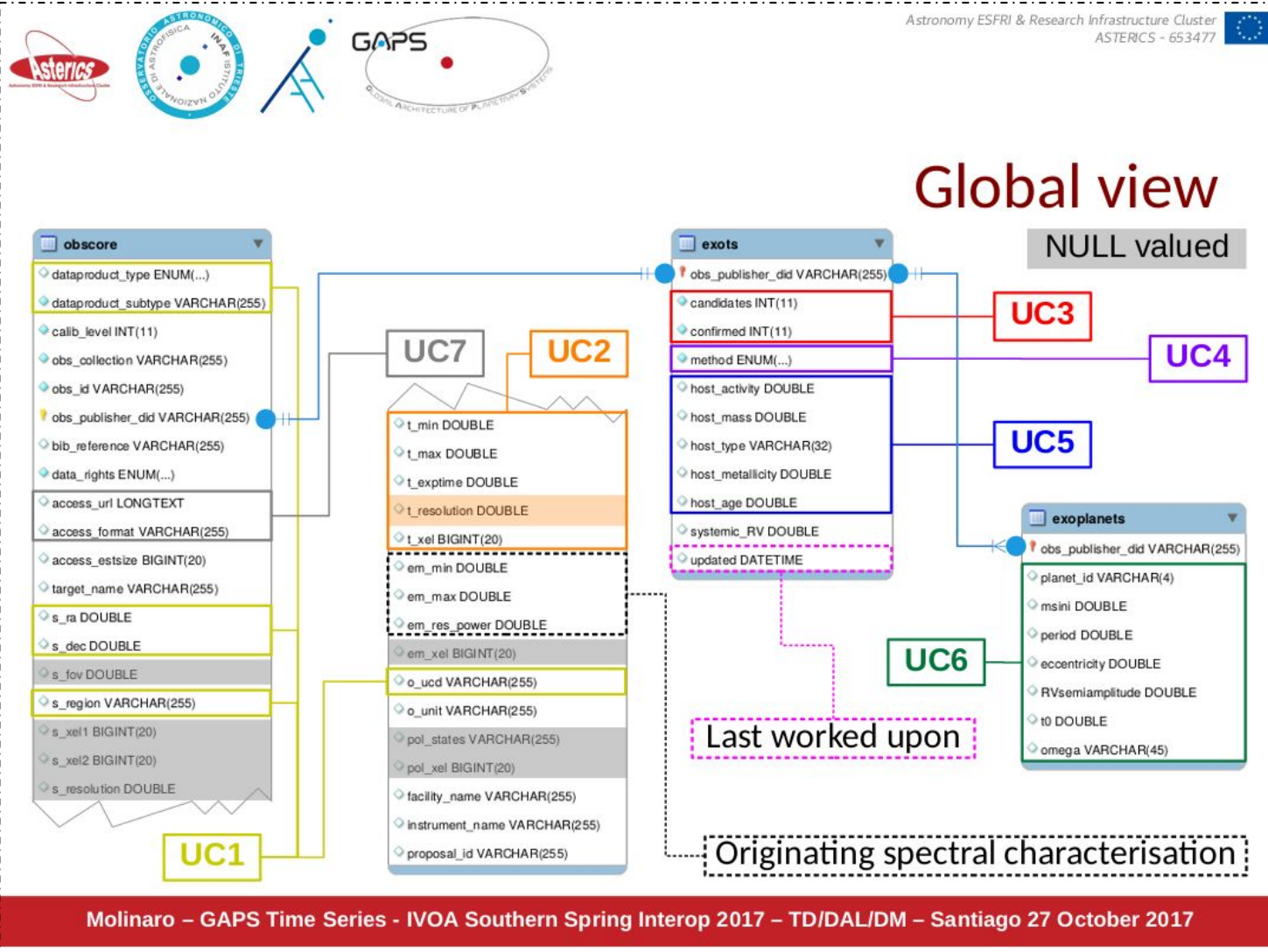
Meeting Report

A face-to-face meeting has been held at INAF-OAPd (Padova, Italy) on Thursday the 22th of June 2017 to discuss the use cases and possible prototyping of a service to deploy dataset consisting of time series of radial velocity produced by the [GAPS](#) project when studying stellar systems for discovery of exoplanets.

- Time Series is one of the GAPS products
- Time Domain is an IVOA priority
- Let's bring GAPS Time Series in the VO



Time Series in VO



ADASS &
IVOA
Reports
October 2017

- Our approach:
- Use Case (UC) driven
 - DataSet discovery
 - ObsCore based

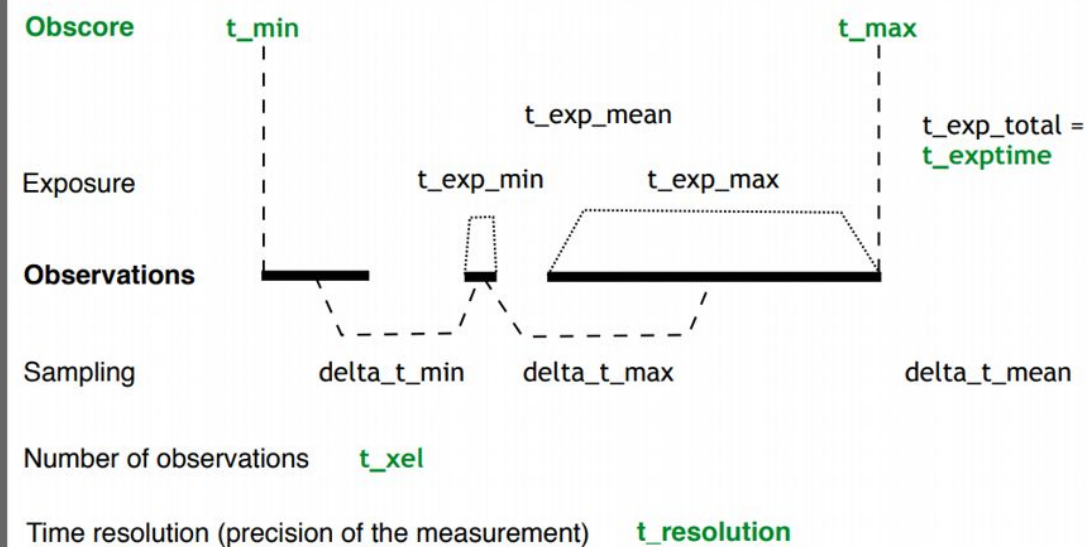
Molinaro – GAPS Time Series - IVOA Southern Spring Interop 2017 – TD/DAL/DM – Santiago 27 October 2017

Time Series in VO

Time Axis Characterisation

May 2018

Time Axis evolution



Not yet finalised. Details may fall into modelling.



M. Molinaro – Exoplanets Time Series & VO – XIV Cong. Nazionale Scienze Planetarie - Bormio 8 February 2018



ObsTAP Service



TAP HOME PAGE

Available resources

- [async](#)
- [tables](#)
- [capabilities](#)
- [availability](#)
- [sync](#)

ADQL query

Query:

```
SELECT *
FROM TAP_SCHEMA.tables;
```

Execution mode: ☐ Asynchronous/Batch ☒ Synchronous

Format:

☐ Result limit: rows (0 to get only metadata ; a value > 0 means a limit)

☐ Duration limit: seconds (a value ≤ 0 means 'default')

Execute!

Page generated by [TAPLibrary](#) v2.0

Name	Unit	Description	UCD	Utype
access_estsize	kbyte	Estimated size of dataset in kilo bytes	phys.size:meta.file	Access.size
access_format		Content format of the dataset	meta.code.mime	Access.format
access_url		URL used to access (download) dataset	meta.ref.url	Access.reference
bib_reference		Service bibliographic reference	meta.bib	Curation.reference
calib_level		Calibration level {0, 1, 2, 3, 4}	meta.code:obs.calib	ObsDataset.calibLevel
datapoint_subtype		Data product specific type	meta.id	ObsDataset.dataProductSubtype
datapoint_type		Logical data product type (image etc.)	meta.id	ObsDataset.dataProductType
data_rights		Public/Secure/Proprietary	meta.code	Curation.rights
delta_t_max				
delta_t_min				
em_max	m	Stop in spectral coordinates	em.wl:stat.max	Char.SpectralAxis.Coverage.Bounds
em_min	m	Start in spectral coordinates	em.wl:stat.min	Char.SpectralAxis.Coverage.Bounds
em_res_power		Value of the resolving power along the spectral axis. (R)	spect.resolution	Char.SpectralAxis.Resolution.Res
em_vel		Number of elements along the spectral axis	meta.number	Char.SpectralAxis.numRins

Service Capabilities

Query Language: ADQL-2.0 Max Rows: Uploads: unavailable

ADQL Text

Mode: Synchronous

```
SELECT * FROM ivoa.obscure
WHERE
  s_ra > 187.6 AND s_ra < 187.7 AND
  s_dec > 22.8 AND s_dec < 22.9 AND
  datapoint_type = 'timeseries' AND
  o_ucl = 'spect.dopplerVeloc.opt'
```

Run Query

...or use whatever programmatic access based on the TAP protocol

ObsTAP Service

Use Case Fulfill

```

SELECT
  obs_collection, dataproduct_type, obs_id, target_name, access_url, access_format
FROM
  obscore
WHERE
  s_ra > 187.6 AND s_ra < 187.7 AND
  s_dec > 22.8 AND s_dec < 22.9 AND
  dataproduct_type = 'timeseries' AND
  o_ucd = 'spect.dopplerVeloc.opt'

```

Table Browser for 14: TAP_14_obscore

	obs_collection	dataproduc...	obs_id	target_name	access_url	access_format
1	GAPS/TimeSeries	timeseries	KP7	HD108874	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP7/KP7.v1.xml	application/x-votable+xml
2	GAPS/TimeSeries	timeseries	KP7	HD108874	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP7/KP7.dat	text/plain

```

SELECT
  target_name, systemic_RV, access_url , planet_id, period, eccentricity
FROM
  obscore AS o
  JOIN
    exots AS s
    ON s.obs_publisher_did = o.obs_publisher_did
  JOIN
    exoplanets AS p
    ON p.obs_publisher_did = s.obs_publisher_did
WHERE
  confirmed IS NOT NULL

```

Table Browser for 12: TAP_12_obscore,exots,exoplanets

	target_name	systemic_RV	access_url	planet_id	period	eccentricity
1	HD108874	-29.6	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP7/KP7.dat	b	395.34	0.142
2	HD108874	-29.6	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP7/KP7.dat	c	1732.2	0.229

ObsTAP Service

Discovery Response

TOPCAT(9): Table Browser



Window Subsets Help



Table Browser for 9: TAP_9_obscore

	obs_collection	dataproduc...	obs_id	target_name	obs_publisher_id	access_url	access_format
9	GAPS/TimeSeries	timeseries	AST01	Tau Boo	ivo://ia2.inaf.it/gaps/dsetdesc?859943eb	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/AST01/AST01.dat	text/plain
10	GAPS/TimeSeries	timeseries	KP22	XO-2 N	ivo://ia2.inaf.it/gaps/dsetdesc?60692363	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP22/KP22.dat	text/plain
11	GAPS/TimeSeries	timeseries	KP44	Tres-4	ivo://ia2.inaf.it/gaps/dsetdesc?e7478dbb	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP44/KP44.dat	text/plain
14	GAPS/TimeSeries	timeseries	KP6	HIP11952	ivo://ia2.inaf.it/gaps/dsetdesc?24846bd2e	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP6/KP6.dat	text/plain
12	GAPS/TimeSeries	timeseries	KP7	HD108874	ivo://ia2.inaf.it/gaps/dsetdesc?474b8c9b	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP7/KP7.dat	text/plain
1	GAPS/TimeSeries	timeseries	KP7	HD108874	ivo://ia2.inaf.it/gaps/dsetdesc?474b8c9b v	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP7/KP7.v1.xml	application/x-votable+xml
2	GAPS/TimeSeries	timeseries	KP76	XO-2 S	ivo://ia2.inaf.it/gaps/dsetdesc?19692bec	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP76/KP76.dat	text/plain
15	GAPS/TimeSeries	timeseries	KP79	KELT-6	ivo://ia2.inaf.it/gaps/dsetdesc?be65b67c	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/KP79/KP79.dat	text/plain
16	GAPS/TimeSeries	timeseries	M87	GJ3998	ivo://ia2.inaf.it/gaps/dsetdesc?a6ecfa77	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/M87/M87.dat	text/plain
3	GAPS/TimeSeries	timeseries	OC102	Pr0211	ivo://ia2.inaf.it/gaps/dsetdesc?306dfb06	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/OC102/OC102.dat	text/plain
4	GAPS/TimeSeries	timeseries	RML11	HAT-P-18	ivo://ia2.inaf.it/gaps/dsetdesc?1045c74d	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/RML11/RML11.dat	text/plain
17	GAPS/TimeSeries	timeseries	RML17	HAT-P-20	ivo://ia2.inaf.it/gaps/dsetdesc?96a2da13	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/RML17/RML17.dat	text/plain
7	GAPS/TimeSeries	timeseries	RML2	Qatar-1	ivo://ia2.inaf.it/gaps/dsetdesc?9a781977	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/RML2/RML2.dat	text/plain
5	GAPS/TimeSeries	timeseries	RML21	Qatar-2	ivo://ia2.inaf.it/gaps/dsetdesc?2de8a219	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/RML21/RML21.dat	text/plain
6	GAPS/TimeSeries	timeseries	RML24	WASP-11/HAT-P-10	ivo://ia2.inaf.it/gaps/dsetdesc?756ca646	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/RML24/RML24.dat	text/plain
8	GAPS/TimeSeries	timeseries	RML6	WASP-43	ivo://ia2.inaf.it/gaps/dsetdesc?7880635ae	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/RML6/RML6.dat	text/plain
13	GAPS/TimeSeries	timeseries	RML8	HAT-P-36	ivo://ia2.inaf.it/gaps/dsetdesc?18b34120	http://twiki.oats.inaf.it/twiki/pub/GAPS/TimeSeries/RML8/RML8.dat	text/plain

- Query response allows
 - Direct access (single format currently)
 - Dataset unique identification (see next steps...)
- Example provided of “annotated” table



ObsTAP Service

Annotated Serialisation

- Improve interoperability
- Share with colleagues
- Preserve metadata information
- Still in progress...

```
<VOTABLE version="1.3" xmlns="http://www.ivoa.net/xml/VOTable/v1.3">
  <!--
    ! VOTable written by STIL version 3.2-1 (uk.ac.starlink.votable.VOTableWriter)
    ! at 2018-03-29T12:21:35
    !-->
  <RESOURCE>
    <!-- Source parameters -->
    <PARAM arraysize="3" datatype="char" name="GAPS name" value="KP7">
      <DESCRIPTION>internal project target identifier</DESCRIPTION>
    </PARAM>
    <PARAM arraysize="12" datatype="char" name="alpha" ucd="pos.eq.ra;meta.main" value="12:30:26.900">
      <DESCRIPTION>Right Ascension of target</DESCRIPTION>
    </PARAM>
    <PARAM arraysize="12" datatype="char" name="delta" ucd="pos.eq.dec;meta.main" value="+22:52:47.30">
      <DESCRIPTION>Declination of target</DESCRIPTION>
    </PARAM>
    <PARAM datatype="float" name="PM alpha" ucd="pos.pm;pos.eq.ra" value="0.1271">
      <DESCRIPTION>Proper motion, alpha component</DESCRIPTION>
    </PARAM>
    <PARAM datatype="float" name="PM delta" ucd="pos.pm;pos.eq.dec" value="-0.0894">
      <DESCRIPTION>Proper motion, delta component</DESCRIPTION>
    </PARAM>
    <PARAM datatype="float" name="Magnitude" ucd="phot.mag;em.opt" unit="mag" value="8.76">
      <DESCRIPTION>Photometric magnitude (optical)</DESCRIPTION>
    </PARAM>
    <PARAM datatype="float" name="B-V" ucd="phot.color;em.opt.b;em.opt.V" unit="mag" value="0.738">
      <DESCRIPTION>B-V color</DESCRIPTION>
    </PARAM>
    <GROUP ID="char" name="characterisation" utype="ts:Char">
      <!-- This is the characterisation of the whole TimeSeries. It replaces Jiri's quantity and gavers "statistics" -->
      <PARAM array:
        <DESCRIPTION>
          <PARAM name="SpatLocationRA" ucd="pos.eq.ra" unit="deg" utype="ts:Char.SpatialAxis.Coverage.Location.Coord.SpatialValue2D[0]" datatype="float" value="187.651"/>
          <PARAM name="SpatLocationDEC" ucd="pos.eq.dec" unit="deg" utype="ts:Char.SpatialAxis.Coverage.Location.Coord.SpatialValue2D[1]" datatype="float" value="+22.88643"/>
          <PARAM name="SpatBoundsSizeRA" ucd="pos.eq.ra;stat.length" unit="deg" utype="ts:Char.Coverage.SpatialAxis.Bounds.CharBox.Size2[0]" datatype="float" value="0.0001"/>
          <PARAM name="SpatBoundsSizeDEC" ucd="pos.eq.dec;stat.length" unit="deg" utype="ts:Char.Coverage.SpatialAxis.Bounds.CharBox.Size2[1]" datatype="float" value="0.0001"/>
          <PARAM name="t_min" ucd="time.start" unit="d" utype="ts:Char.TimeAxis.Coverage.bounds.StartTime" datatype="float" value="2456266.77166"/>
          <PARAM name="t_max" ucd="time.stop" unit="d" utype="ts:Char.TimeAxis.Coverage.bounds.StopTime" datatype="float" value="2457790.764710648"/>
          <PARAM name="t_mean" ucd="time" unit="d" utype="ts:Char.TimeAxis.Coverage.location.TimeInstant" datatype="float" value="2456270"/>
          <PARAM name="t_exptime" ucd="time.duration" unit="d" utype="ts:Char.TimeAxis.Coverage.support.Extent" datatype="float" value="84008.801"/>
          <PARAM name="t_resolution" ucd="time.resolution" unit="d" utype="ts:Char.TimeAxis.resolution.RefVal" datatype="float" value="NaN"/>
          <PARAM name="delta_t_min" ucd="time" unit="d" utype="ts:Char.TimeAxis.sampling.bounds.SamplingPrecision.TimeStart" datatype="float" value="0.0002893517"/>
          <PARAM name="delta_t_max" ucd="time" unit="d" utype="ts:Char.TimeAxis.sampling.bounds.SamplingPrecision.TimeStop" datatype="float" value="298.2966319453"/>
          <PARAM name="em_min" ucd="em.wl;sta.min" unit="m" utype="ts:Char.SpectralAxis.Coverage.Bounds.Limits.LoLimit" datatype="float" value="0.000000383"/>
          <PARAM name="em_max" ucd="em.wl;sta.max" unit="m" utype="ts:Char.SpectralAxis.Coverage.Bounds.Limits.HiLimit" datatype="float" value="0.000000690"/>
        </PARAM>
      </DESCRIPTION>
    </GROUP>
```



Next Steps

- Finalise serialisation
 - Requires model annotations
- DataLink solution
 - Complete time series dataset description
 - Allow multi-format dataset access
- Register the resource and service(s)
 - Simple positional search can be done through a Cone Search
 - Easier client approach



Thank You for Your Attention

