

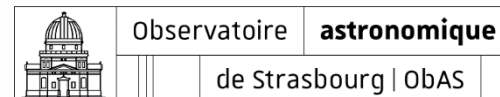


Aladin on time !

STMOC: Where & When in few milliseconds

Interop meeting – 13-17 May 2019

Pierre Fernique
Daniel Durand, Ada Nebot, Thomas Boch, FX Pineau
and others contributors



□ The plan

1. Time handle in Aladin
2. MOC, TMOC, STMOC
3. Live Demo

A two years work...

ALADIN

Temporal exploration in Aladin
Time series and T-MOC

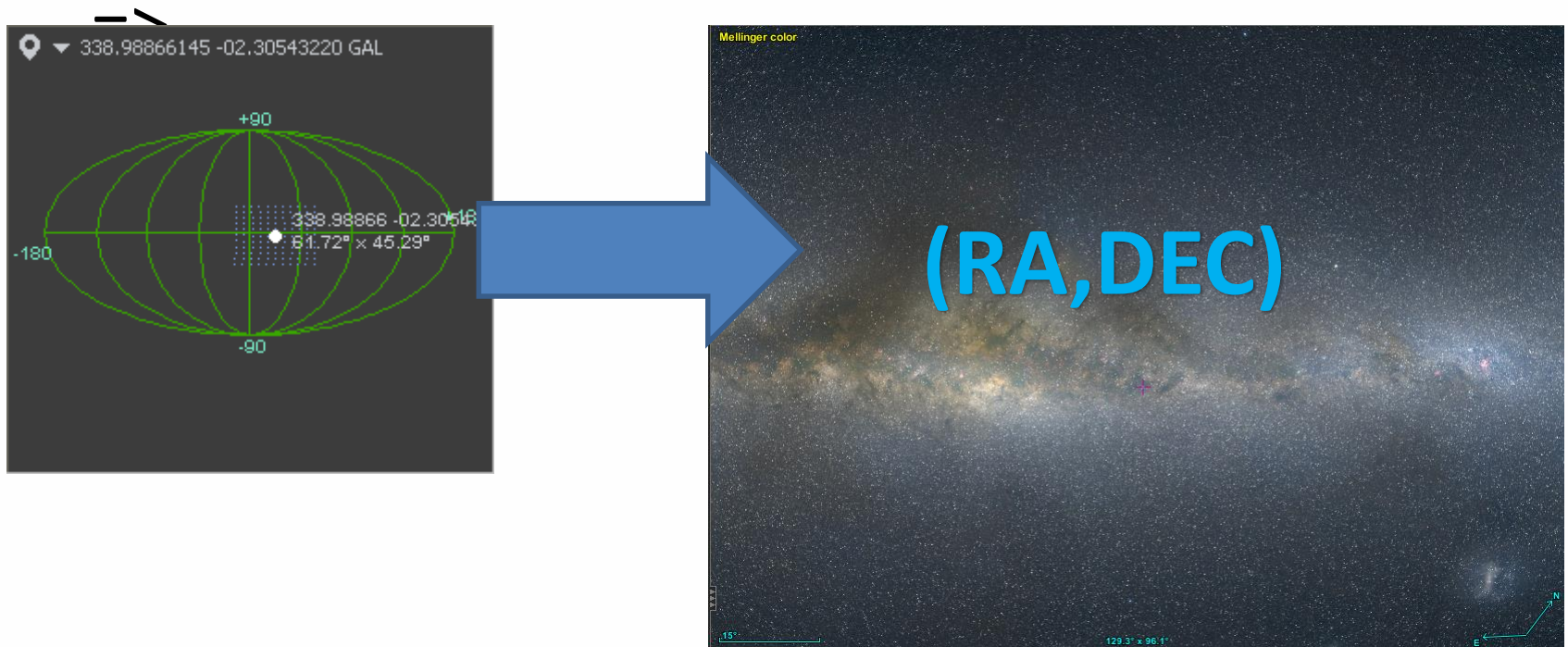
Interop meeting – 28 May to 1 June 2018

Pierre Fernique
Daniel Durand, Thomas Boch, Ada Nebot, FX Pineau
and others contributors



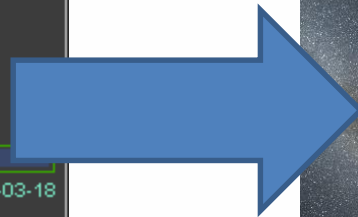
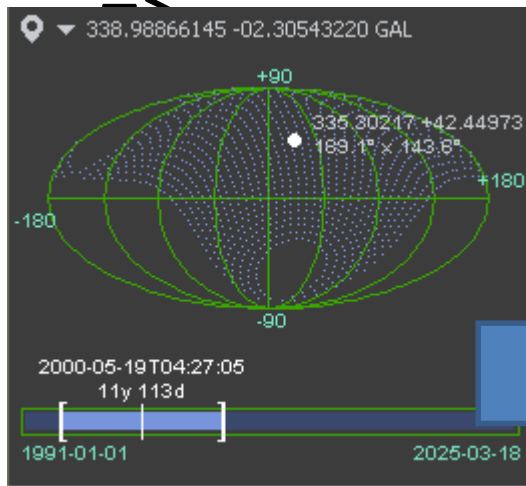
□ Aladin until now...

- **Space view and control** only
Aladin = Views on the celestial sphere



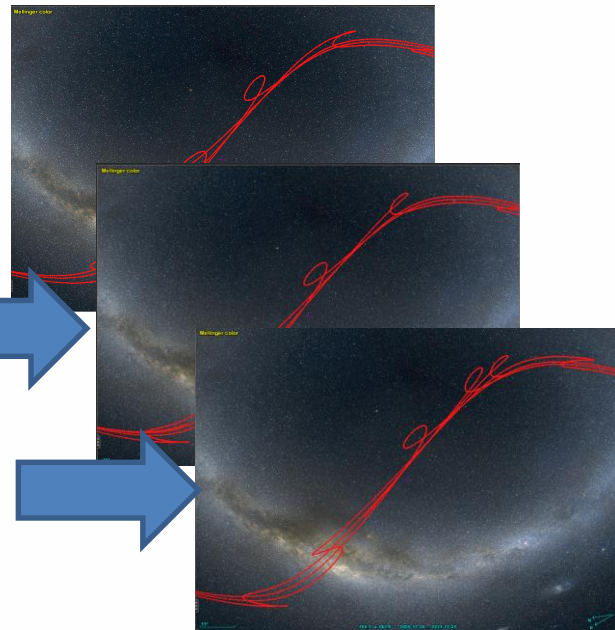
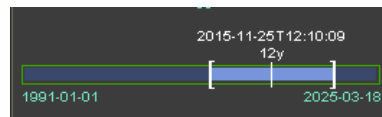
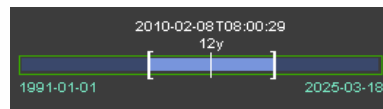
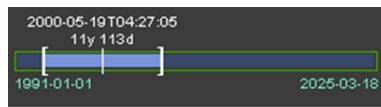
□ Aladin today

- Space + **Time** view and control
=> Ceslestial sphere + **calendar**

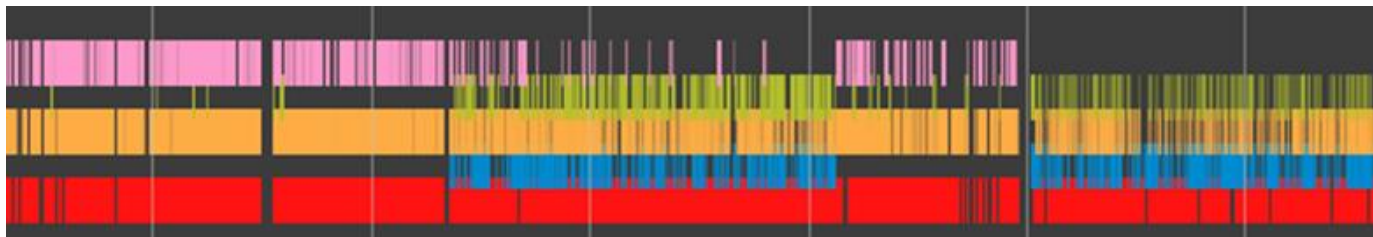


□ Which data are concerned ?

1. Catalogs with epoch



2. Time Coverage (TMOC)



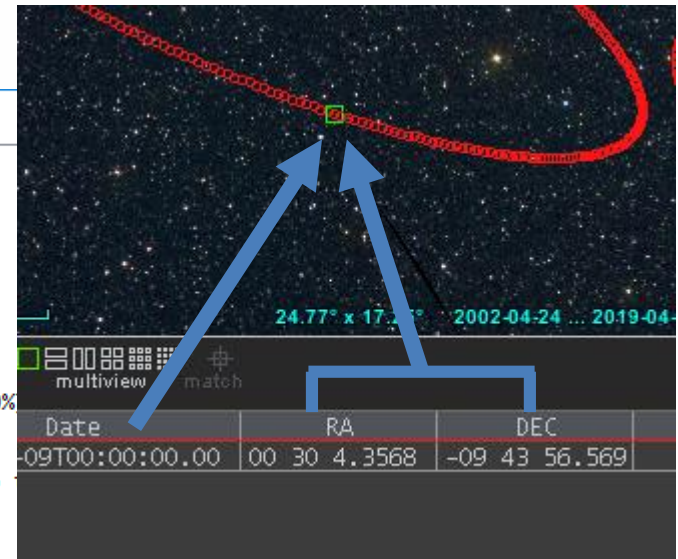
□ How to do Time Discovery

- By default: using **heuristic rules**
=> not too bad but mistakes are possible
- If lucky we do have access to a **TIMESYS**
=> Solves the problem!

```
Catalog information
Positional ephemeris
Parsing information:
VOTable format
.Table Miriade.ephemcc.results
-assuming Time column 2 (proba=90.0%)
-assuming RADEC in sexagesimal column 3 for RA and 4 for DEC
 [RA=2 (proba=90.0%) DE=3 (proba=90.1%) PMRA=-1 (proba=0.0%) PMDEC=-1 (proba=0.0%)
-Coordinate system references found:
 ID="t3-coosys-1" => eq_FK5 Eq=J2000
 => RA/DEC coordinate conversion not required: ref="t3-coosys-1" => FK5(J2000.0)
-No time system reference found... TCB/BARYCENTER
-Ref time system: format=ISOTIME timescale=TCB reposition=BARYCENTER

Catalog parsed in 0.875s (28571 objects per sec)
```

(RA, DEC, JD)

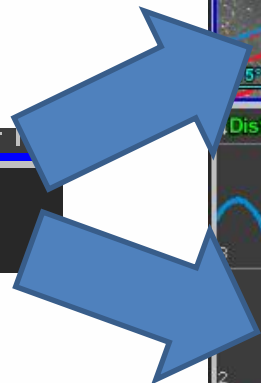
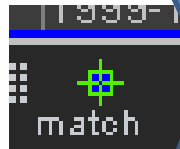


□ A unique time system

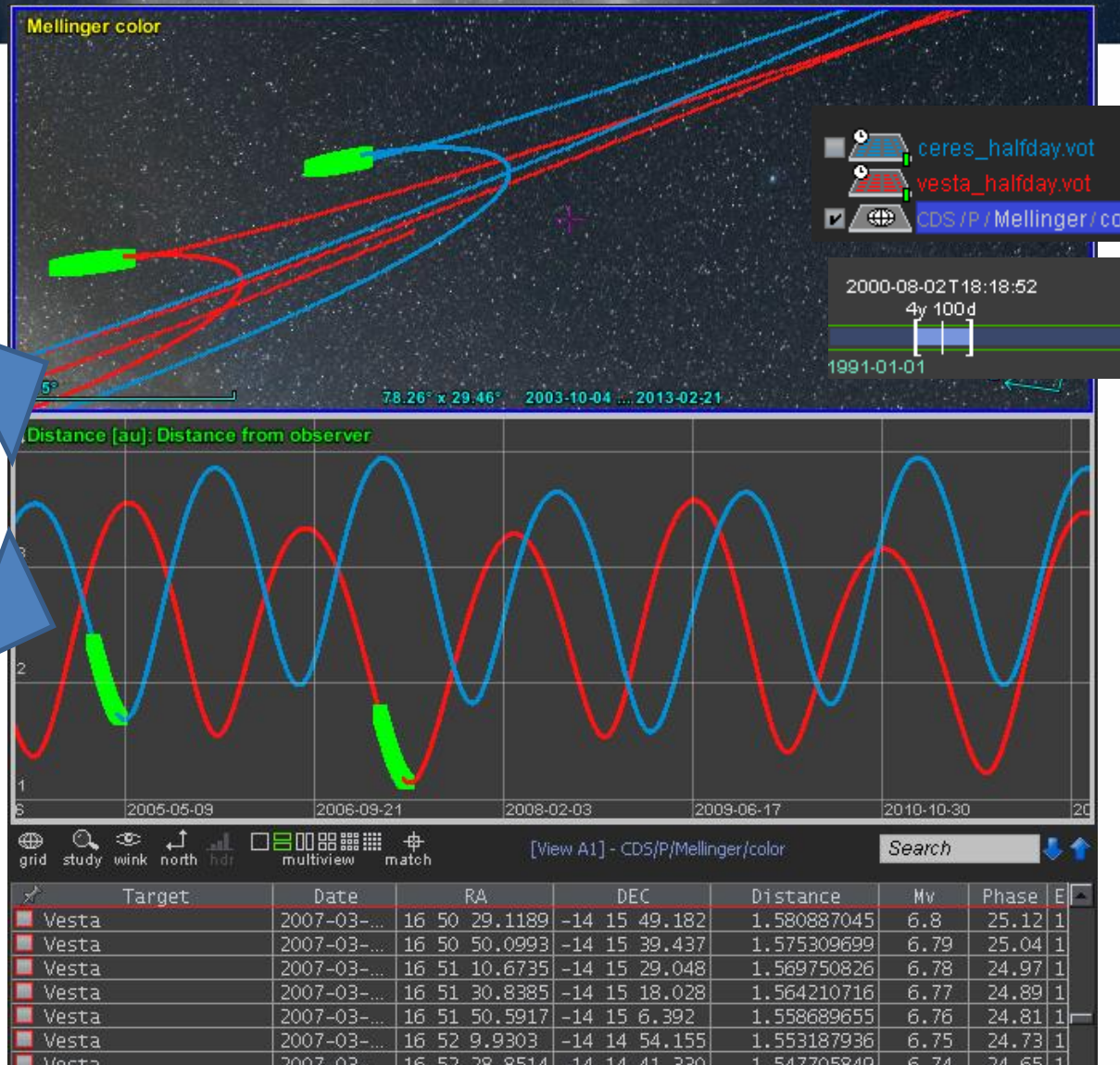
- All Aladin times are converted to or assuming to be in **TCB Barycenter**
- Using Time SOFA routines (JSOFA lib – thanks!)
- Ephemerid issue :
 - => Warning in Aladin if the conversion is not possible (may depend on the Earth position)
 - => time error always < 20mn

□ Time display

- Spatial View
- **Time View**
(=timeplot)



- Overlays,
Synchronization,
object selection,
...





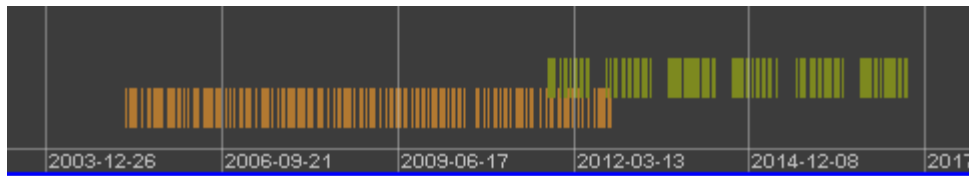
Part 2.

MOC, TMOC and STMOC

□ Time Coverage

One year ago

- We studied TMOC
= Time MultiOrder Coverage
- A VO dedicated system for manipulating time:
Fast, interoperable, multi-resolutions, packageable...
=> Just by reusing MOC lib for Time (T-MOC)



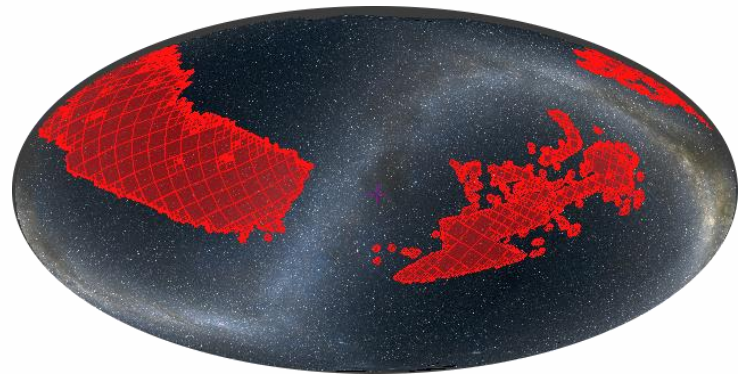
- TMOC conventions:
 - JD(TDB,Barycentric,no offset)
 - Order 29 -> 1 μ s TMOC resolution
 - Allow to describe 9133 years from JD=0

- (S)MOC + TMOC: you can manipulate When OR Where
=> but not both together.

□ When **AND** Where !

Today

- The **STMOC** = Space Time MultiOrder Coverage
- Merge together both dimensions in a unique MOC in order to have simultaneously space and time coverage



2 years CDS&Co R&D
driven by
IVOA effort on time

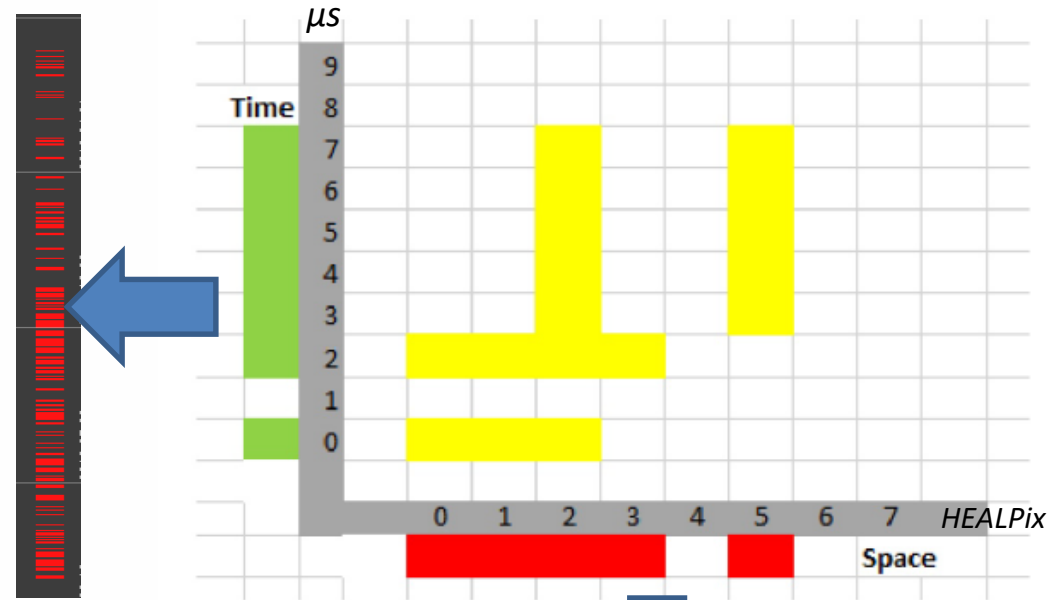


STMOC live in video

The screenshot displays the ALADIN software interface. At the top, the menu bar includes "File", "Edit", "Image", "Catalog", "Overlay", "Coverage", "Tool", "View", "Interop", and "Help". The command line shows "Command 05:58:14.19 +21:51:01.1". Below the command line, there is a row of data sources: "DSS", "DSS-red", "PanSTARRS", "SDSS", "2MASS", "WISE", "GALEX", "PLANCK", "AKARI", "XMM", "Gaia", "Simbad", and "NED". The main window shows a 3D visualization of a stellar stream in red, overlaid on a dark sky background. The stream is composed of a grid of points. The interface includes a toolbar on the right with icons for "select", "pan", "dist", "phot", "draw", "tag", "moc", "grid", "crop", "cont", "print", "prop", and "del". The control panel on the right shows the selected object "CDS/P/Mellinger/color" and various sliders for "epoch", "size", "dens.", "cube", "opac.", and "zoom". A small inset window shows a 2D projection of the stream with coordinates "2457044.63376 +265.20000 ICRS" and "09:20:36.02 +17:52:02.2" and "360° x 180°". The bottom status bar shows "[Plane #1] - CDS/P/Mellinger/color - 1 object drawn (-1ms)[RefForVisibleView, Viewable, Activated, AskActivated, Ref, FlagOk]" and the date "2012-09-23" to "2017-05-22".

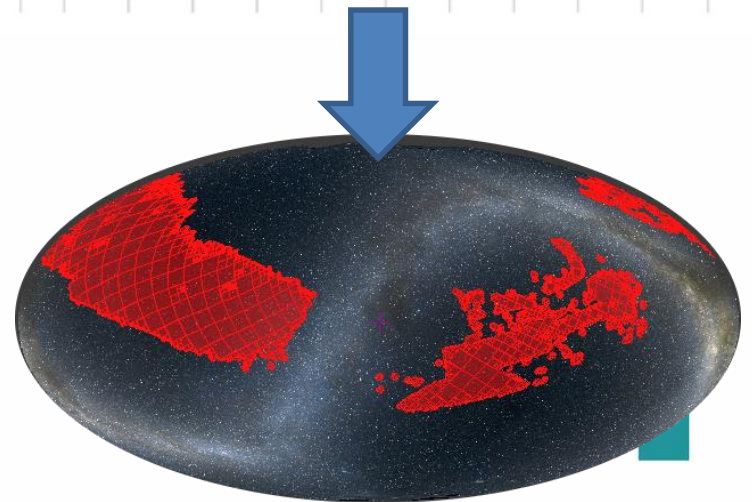
□ STMOC concept & challenge

- (S)MOC = a list of numbers (red)
- TMOC is also a list of numbers (green)
- **STMOC** is the 2D table of numbers (yellow)



=> The challenge:

How to describe and manipulate a 2D table efficiently

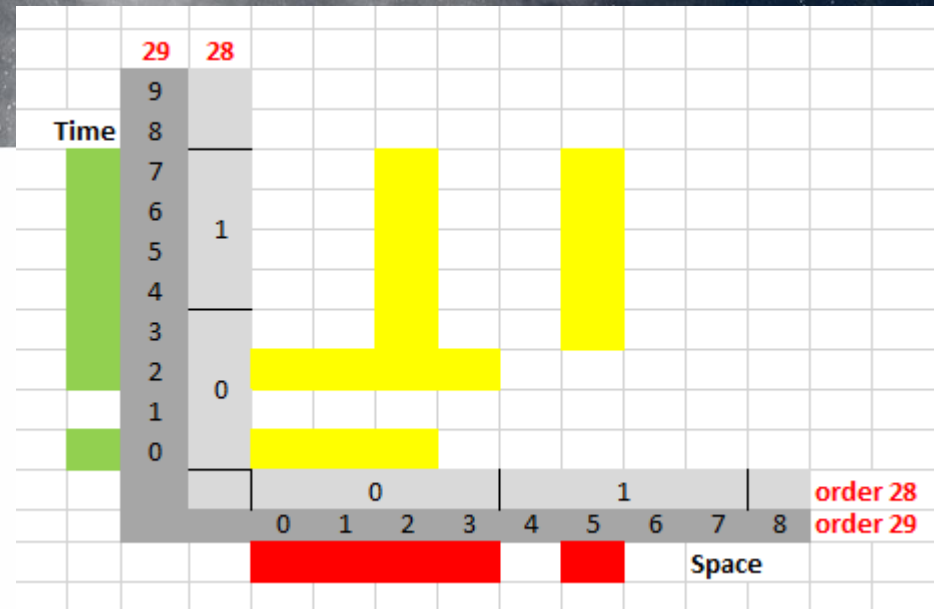


□ STMOC study

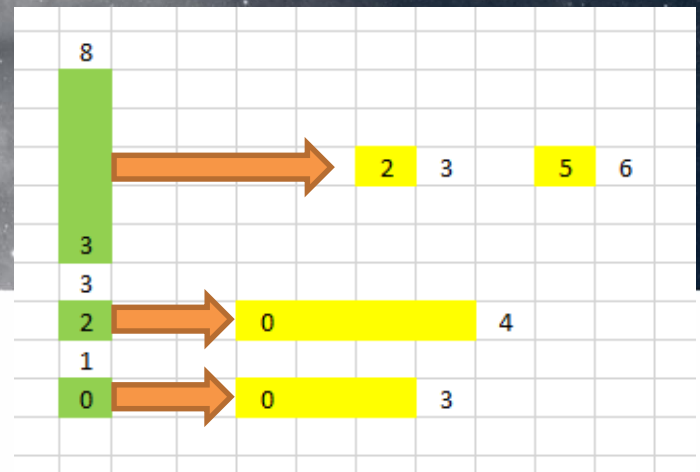
- Existing MOC codings:
 - List of numbers, hierarchized => MOC
 - List of ranges at high order => internal usage

⇒ List of indices (ex: 29/0-3,5...)
List of longs (FITS/NUNIQ)

- For STMOC, 2 possible extensions :
 - Global numbering => but will force to use the same resolution for space and time (=> not a good idea)
 - Two independent arrays**(=> it works !)



Internal coding => Client choice



CDS choice to manipulate STMOC:

- We use a TMOC expressed as a list of time ranges at highest level (29)

$[tmin1..tmax1[, [tmin2..tmax2[, \dots [tminN..tmaxN[$

- Each of these ranges is associated to a regular MOC (spatial) expressed either:

- List of space ranges at highest level (29),

$[npixmin1..npixmax1[\dots [npixminM..npixmaxM[$

- Or list of hierarchical numbers

$order/npix, npix \dots order/npix, \dots$



□ Size and performance

- STMOC **generation** from a catalog of 211K sources (ACS/HST observations)

Using RA,DE,JD

- T-Order 10 (3d), S-Order 10 (3.4') => **0.25s, 313KB**
- S-Order 13 (26'') T-Order 14 (18mn) => **0.8s, 1.6MB**

Using s_region,JD

- T-Order 10 (3d) S-Order 10 (3.4') => **9.8s, 654KB**
- T-Order 14 (18mn), S-Order 13 (26'') => **59s, 15.6MB**

- STMOC **operations**

(unions, intersect., subtrac., compl.)

=> about **2ms** to **50ms**

- **Filtering** a catalog by STMOC

=> **300ms** for 800K sources => 22K matches

Success keys:
+ 1. Unique canonical form
+ 2. multi resolution
+ 3. Dychotomy based on sorted arrays
=> versatil,
fast & compact

□ In details

ACS/HST log – 211453 observations

Torder	Sorder	Time resolution	Space resolution	# time ranges	Size	Time to generate
29	29	1 μ s	393.2 μ as	126636	4.2MB	3.4s
20	14	262ms	12.9"	126636	3,9MB	3s
14	20	~18mn	201.3mas	70632	2.8MB	2.2s
14	14	~18mn	12.9"	52732	1.8MB	1.4s
14	10	~18mn	3.245'	43843	1.4MB	1.2s
10	14	~3d4h	12.9"	1856	498KB	0.3s
10	10	~3d4h	3.245'	1854	314KB	0.27s
3	3	~143y	7.329°	1	342B	0.4s

Operations on STMOCs

ACS	Saturn	Union	Inter
29/29	29/29	19ms	11ms
14/20	20/14	8ms	3ms
14/14	14/14	5ms	2ms
10/14	14/10	13ms	26ms
3/3	3/3	0ms	0ms

Saturn ephemerid – 20K positions

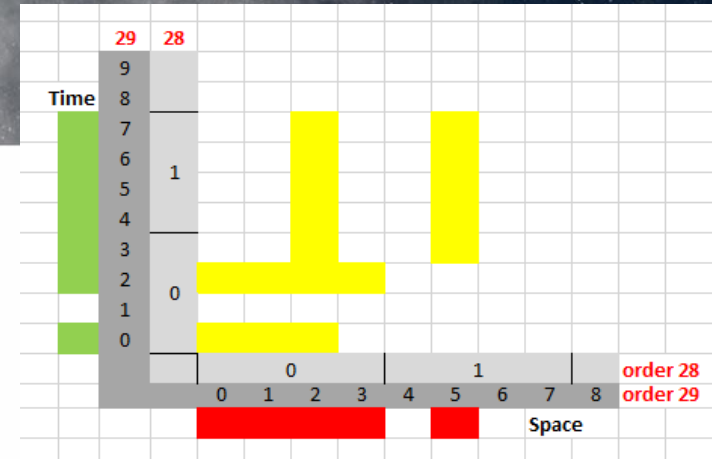
Torder	Sorder	Time resolution	Space resolution	# time ranges	Size	Time to generate
29	29	1 μ s	393.2 μ as	19994	625KB	92ms
20	14	262ms	12.9"	19994	625KB	83ms
14	20	~18mn	201.3mas	19994	625KB	77ms
14	14	~18mn	12.9"	19994	625KB	51ms
14	10	~18mn	3.245'	19994	625KB	98ms
10	14	~3d4h	12.9"	3143	353KB	47ms
10	10	~3d4h	3.245'	3076	197KB	47ms
3	3	~143y	7.329°	2	532B	26ms

Catalog filtering by STMOC

STMOC	Catalog	Time	Matches
ACS 14/14	Saturn	30ms	4
Saturn 14/14	ACS	75ms	23

STMOC proposed serializations

- ASCII serialization:**
 => regular MOC notation with 's' and 't' prefixes:
 t29/0 s29/0-2 t29/2 s28/0 t28/1 29/3 s29/2,5



if no order specified, we assume deepest order
 = Notation « a la battle ships »
 ex: **t0s0-2 t2s0-3 t3-7s2,5**

- Binary serialization:** FITS binary table, storing alternatively time range, associated space ranges

We use the 64th bit to distinguish time or space values
 => negative values for time
 We introduce 3 new FITS keys:

MOC = *SPACETIME*, **ORDERING** = *RANGE29*, **TORDER** = *nn*

-0 }
 -1 }
 0 }
 3 }
 -2 }
 -3 }
 0 }
 4 }
 -3 }
 -8 }
 2 }
 3 }
 5 }
 6 }



□ The live demo...

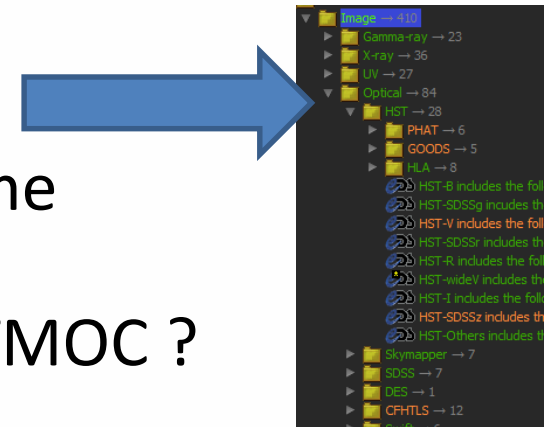
The use-case:
Retrieve all WFPC2/HST observations matching
an ephemerid of Saturn... in a few seconds

*Please do not load the net for
the next 5 minutes...thanks*



□ Next steps

- STMOCs from **VizieR catalogs** and **HiPS**, why not precomputed for **solar system body ephemerids** ?
- Ingested in CDS **MocServer**:
=> Aladin Resource Tree by Space & Time
- IVOA 2.0 MOC for SMOC, TMOC and STMOC ?
=> an **STMOC IVOA note** is ready (Durand, Fernique, Nebot & Co)
- VO registry coverage by STMOC ?



□ Last but not least...

And now ... we can push the same mechanism for:

- **Alternate dimension** => ex: **Space-Redshift** MOC
- Or even to introduce a **third dimension**
=> **ST_E-MOC** = Space-Time-**Energy** MOC

To be
continued

□ Do it yourself...

- Proto available for tests, explorations, ...
<http://aladin.u-strasbg.fr/java/AladinProto.jar>



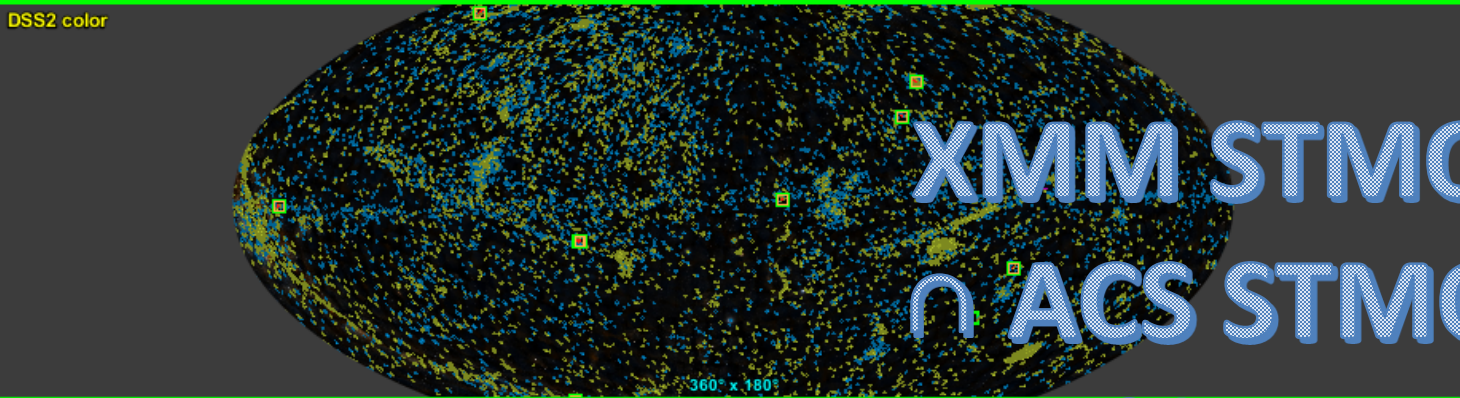
Command 01:38:35.57 -31:29:25.2

Frame ICRS

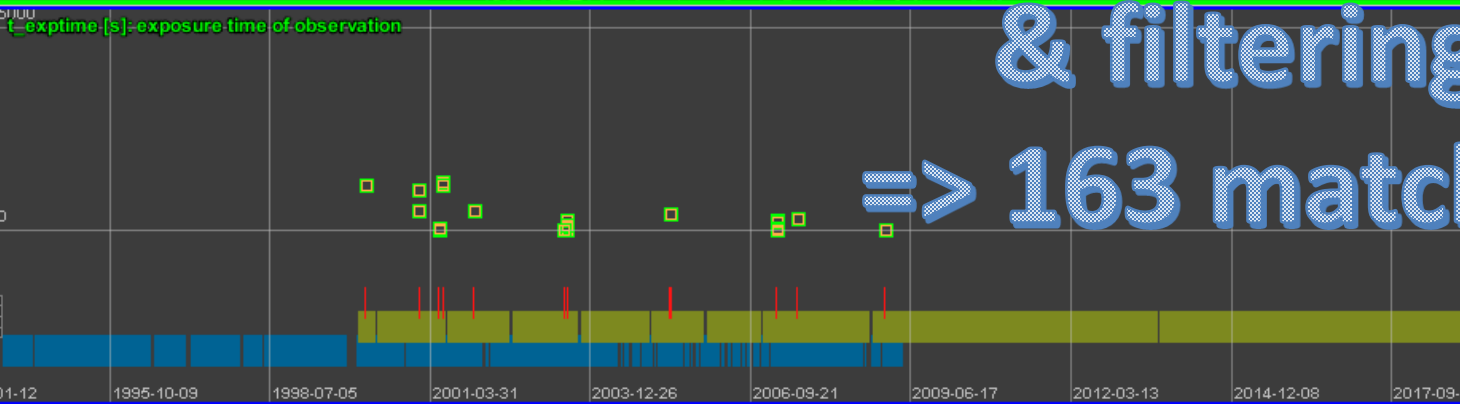
Projection Aitoff



DSS DSS-red PanSTARRS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Gaia Simbad NED +



XMM STMOC
ACS STMOC
& filtering
=> 163 matches



select
pan
phot
tag
moc
spect
filter
cross
y
rgb
epoch
size
dens.
cube
opac.
zoom

- 00WFPC2.vot~1
- int CDS-B-xmm-xmmlog.xml
- CDS-B-xmm-xmmlog.xml ST
- CDS-B-xmm-xmmlog.xml
- 00WFPC2.vot STMOC
- 00WFPC2.vot
- CDS/P/DSS2/color

epoch -
size -
dens. -
cube -
opac. -
zoom -

u2e60601t - Click on it to get details Search

access_url	obs_id	s_ra	s_dec	s_region	t_min	t_max	t_exptime	em_min	em_max
https://...	ub60460cm	161.2655...	-59.6844...	FoV	54841.49...	54841.49...	1.0	2.380099...	2.775199...
https://...	ub604805m	161.2657...	-59.6844...	FoV	54845.43...	54845.43...	1.0	3.1422E-7	3.516400...
https://...	ub604606m	161.2657...	-59.6844...	FoV	54841.44...	54841.44...	1.0	2.380099...	2.775199...
https://...	ub604802m	161.2654...	-59.6843...	FoV	54845.42...	54845.42...	1.0	3.1422E-7	3.516400...
https://...	ub604602m	161.2654...	-59.6843...	FoV	54841.43...	54841.43...	1.0	3.1422E-7	3.516400...
https://...	ub60480bm	161.2655...	-59.6845...	FoV	54845.49...	54845.49...	1.0	3.1422E-7	3.516400...
https://...	u9mm0209m	257.4707...	-22.2219...	FoV	54167.25...	54167.25...	12.0	4.998900...	5.0257...
https://...	u9mm0205m	257.4694...	-22.2210...	FoV	54167.24...	54167.24...	3.0	6.708599...	6.7558...

cont
pixel
prop
del

23:58:33.59869 +00:21:36.0005 ICR

2006-06-14T21:10:15
26y 137 d

1993-12-18 2009-05-12

Aladin v10.1 *** PROTOTYPE VERSION (based on v10.126) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Command Frame ICRS Projection Tangent

DSS DSS-red PanSTARRS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Gaia Simbad NED +

Mellinger color

Jupiter eph. STMOC
 ∩ ACS STMOC
 & filtering
 => datalink

select pan dist phot 4g moc

jupiter_halfday.vot STMOC

- Start: 1990-12-29T22:27:11
- End: 2018-05-16T06:08:13
- # Space: 102.2°^2, 0.248% of sky
- Space res: 6.871"
- Best space order: 10
- Size: 195,33KB

WFC3 x Saturn
 WFC3.vot
 jupiter_halfday.vot STMOC
 jupiter_halfday.vot
 idg212h9q_drc.jpg?RUNID=rld29jdc3g7cnw1x
 CDS/P / Mellinger / color

approach size rgb dens cube assoc opac. zoom

grid study wink north hdr multiview match [Plane @4] - jupiter_halfday.vot STMOC - drawn in 9ms[CanBeTransp, Viewable, Activated, AskActivated, FlagOk] Search

access_url	obs_id	target_n...	s_ra	s_dec	s_region	t_min	t_max	t_expti...Δ	em_min	em_max
https://...	idg212h9q	JUPITER-...	228.6339...	-16.6978...	FoV	58225.26...	58225.26...	0.48	5.075E-7	5.865999...
https://...	idg212h9q	JUPITER-...	228.6339...	-16.6978...	FoV	58225.26...	58225.26...	0.48	5.075E-7	5.865999...
https://...	idg214htq	JUPITER-...	228.6204...	-16.6941...	FoV	58225.40...	58225.40...	0.48	5.075E-7	5.865999...
https://...	idg214htq	JUPITER-...	228.6204...	-16.6941...	FoV	58225.40...	58225.40...	0.48	5.075E-7	5.865999...
https://...	ic3g03siq	JUPITER	74.73393...	21.87942...	FoV	56190.13...	56190.13...	0.48	7.209000...	8.062000...
https://...	ic3g03siq	JUPITER	74.73393...	21.87942...	FoV	56190.13...	56190.13...	0.48	7.209000...	8.062000...
https://...	ic3g03sgq	JUPITER	74.73367...	21.87940...	FoV	56190.13...	56190.13...	0.48	7.209000...	8.062000...
https://...	ic3g03sgq	JUPITER	74.73367...	21.87940...	FoV	56190.13...	56190.13...	0.48	7.209000...	8.062000...
https://...	ic3g02s5q	JUPITER	74.73057...	21.87915...	FoV	56190.07...	56190.07...	0.48	7.209000...	8.062000...

1990-12-29 1,349' x 1,420' 2018-04-17