# Aladin on time !

## STMOC: Where & When in few milliseconds

Interop meeting – 13-17 May 2019

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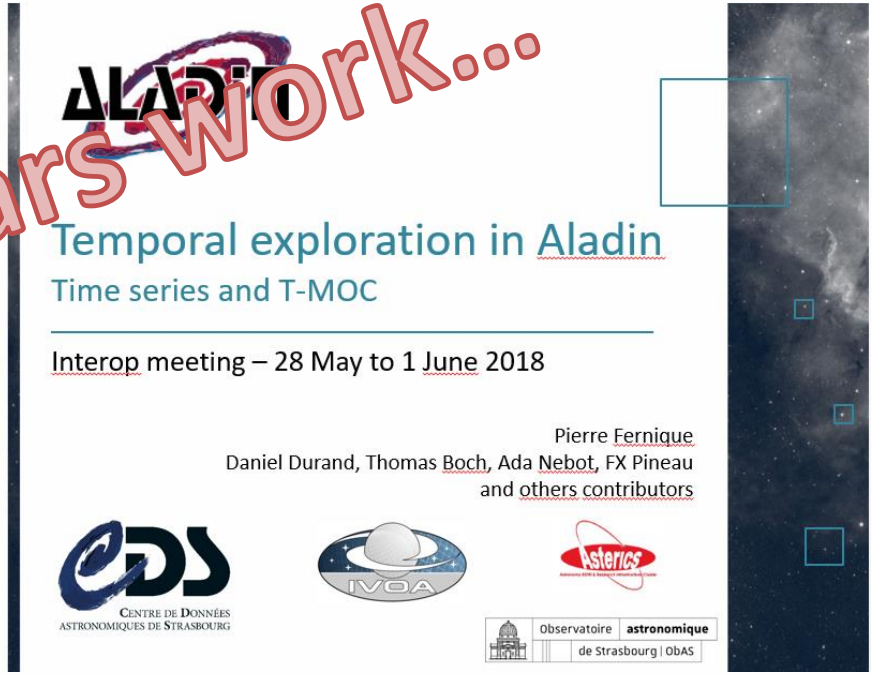
CENTRE DE DONNÉES
ASTRONOMIQUES DE STRASBOURG

Observatoire astronomique de Strasbourg | ObAS

# The plan

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

A two years work...

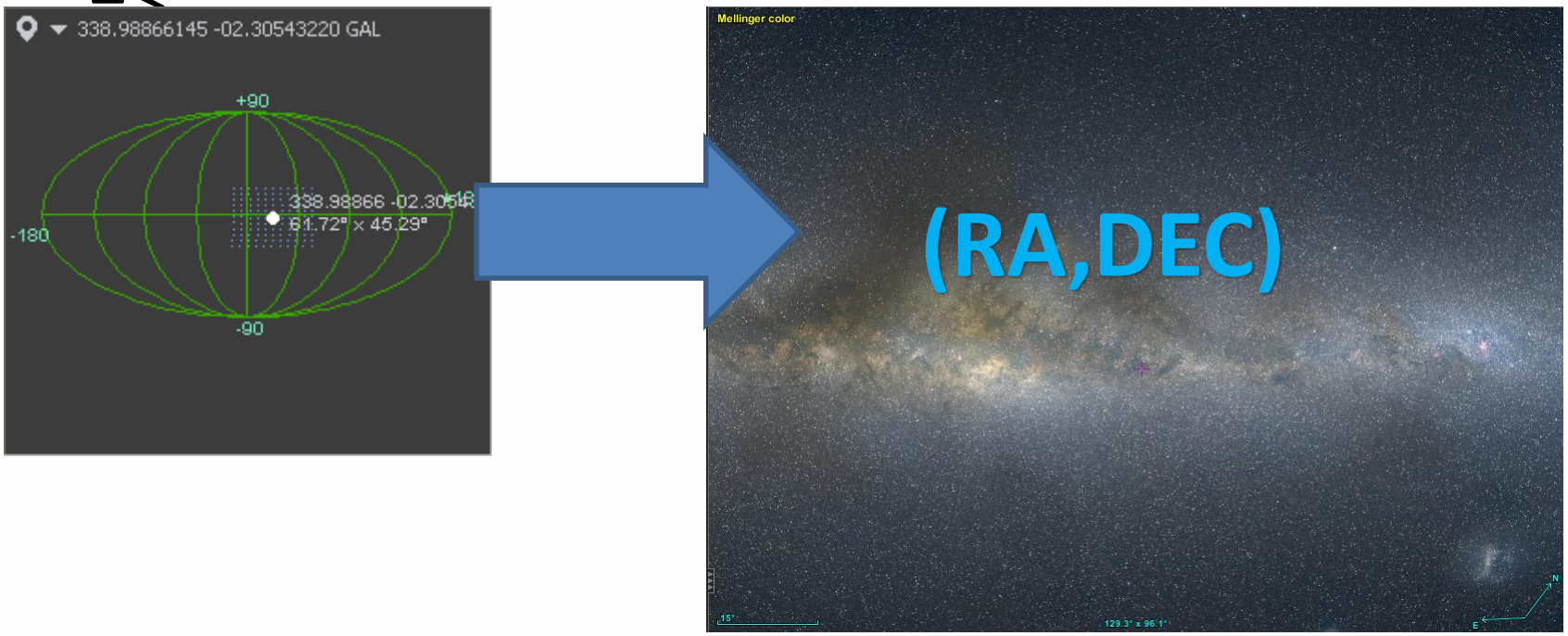


# Aladin until now…

- **Space** view and control only

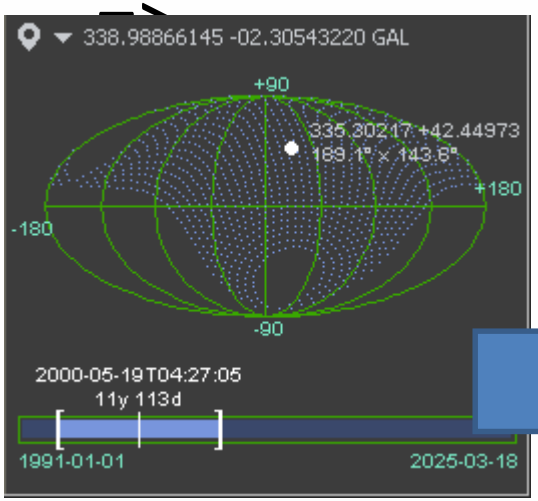
  Aladin = Views on the celestial sphere

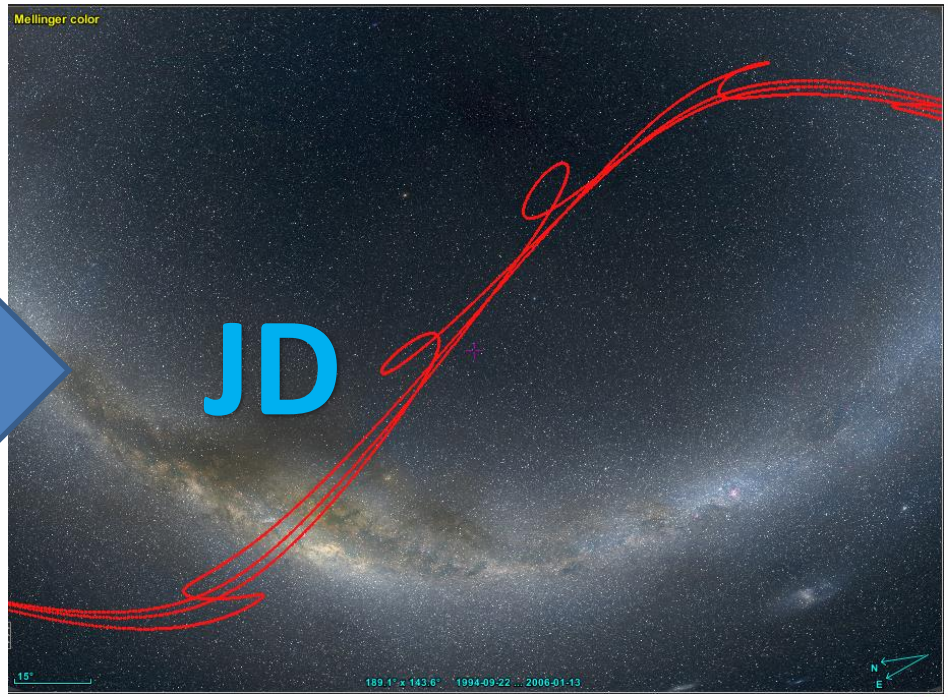
  =>



# Aladin today

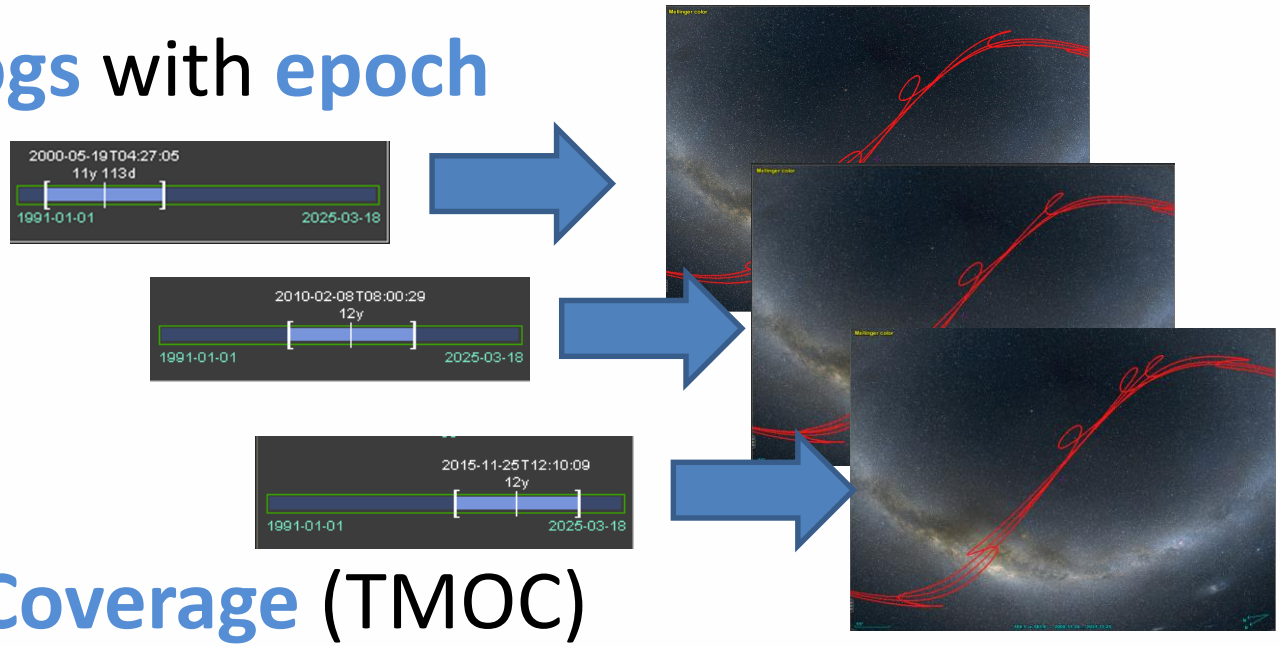
- Space + **Time** view and control
  => Ceslestial sphere + **calendar**



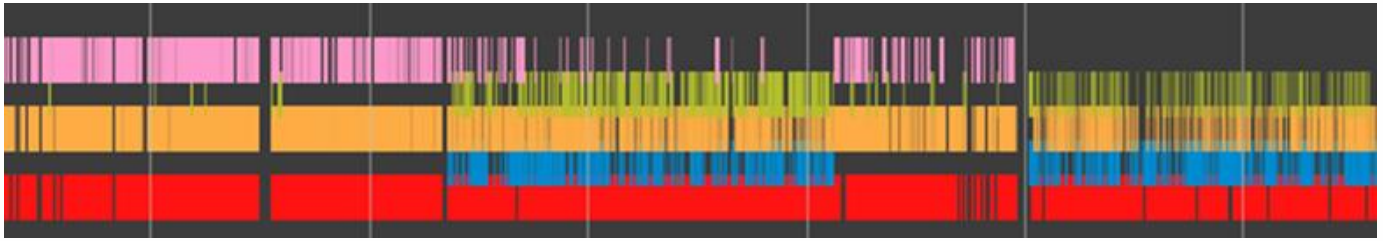



# Which data are concerned ?

1. **Catalogs** with **epoch**



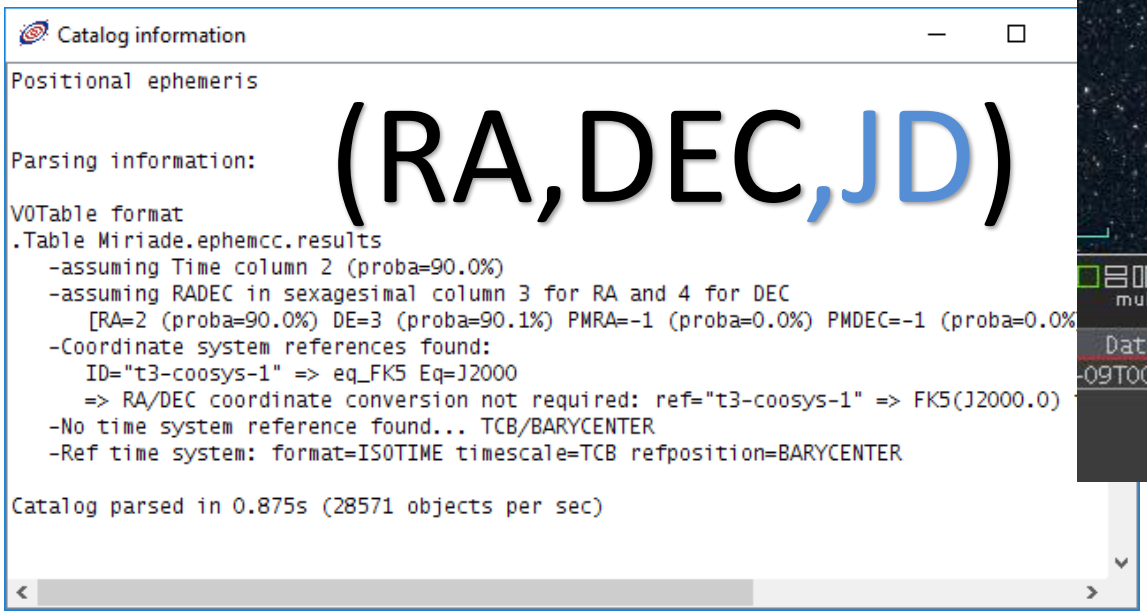

2. Time **Coverage** (TMOC)

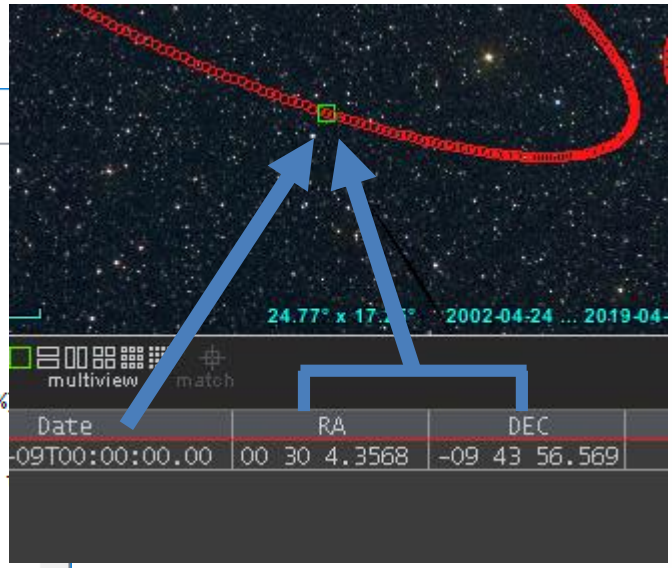


# How to do Time Discovery

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

(RA,DEC,JD)



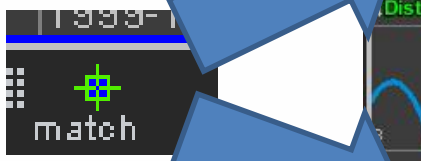



# A unique time system

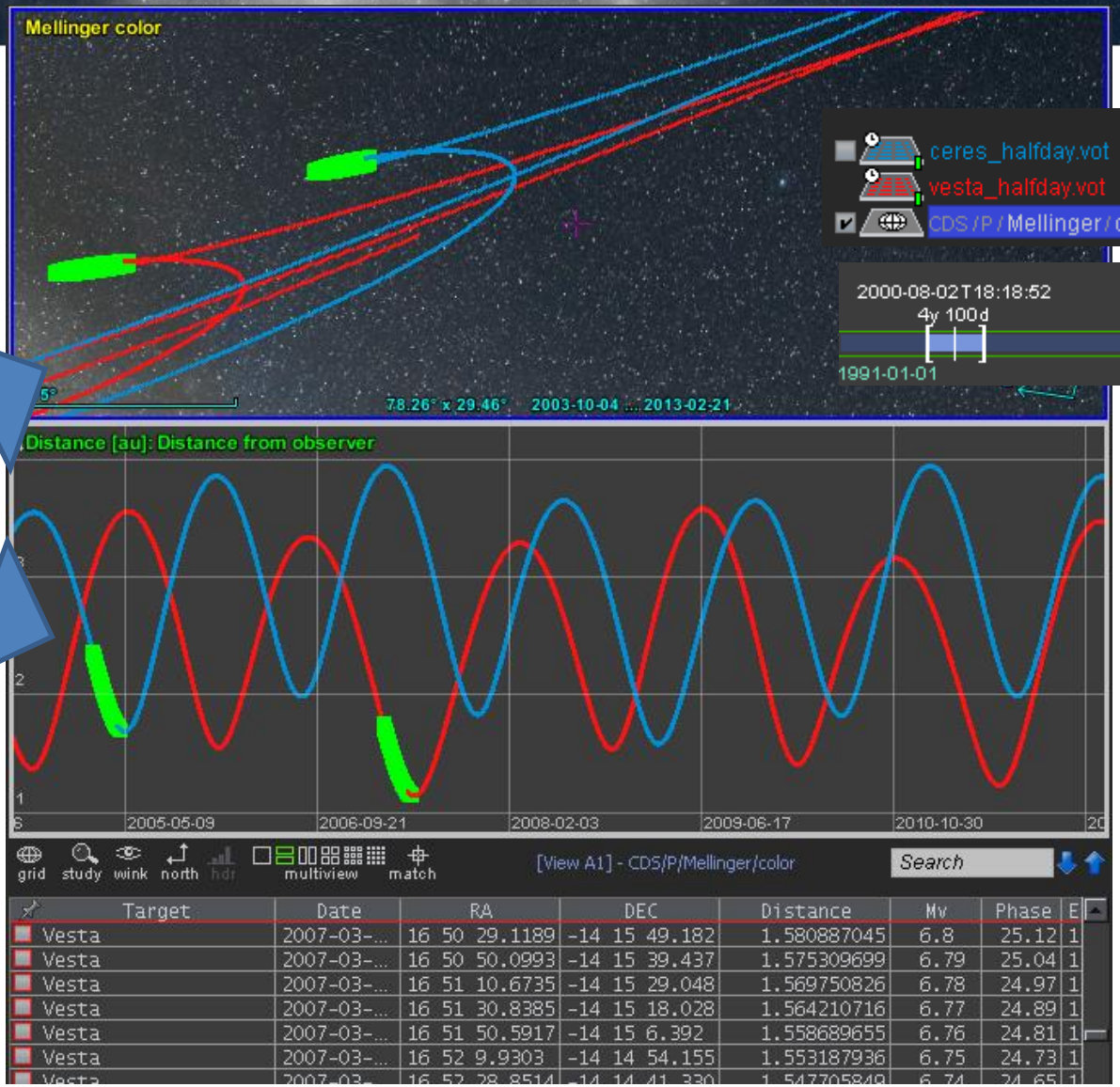
- All Aladin times are converted to or assuming to be in **TCB Barycenter**
- Using Time SOFA routines (JSOFA lib – thanks!)
- Ephemerid issue :
  => Warning in Aladin if the conversion is not possible (may depend on the Earth position)
  => time error always < 20mn

# Time display

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




- Overlays, Synchronization, object selection, …

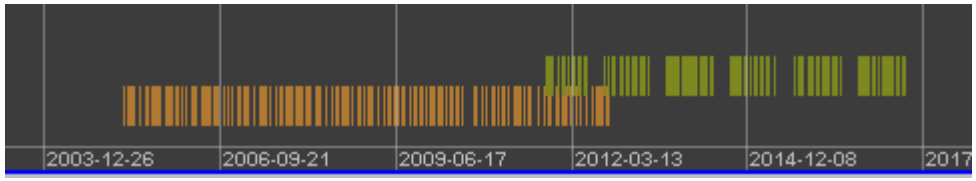


# Part 2.
# MOC, TMOC and STMOC

# 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)



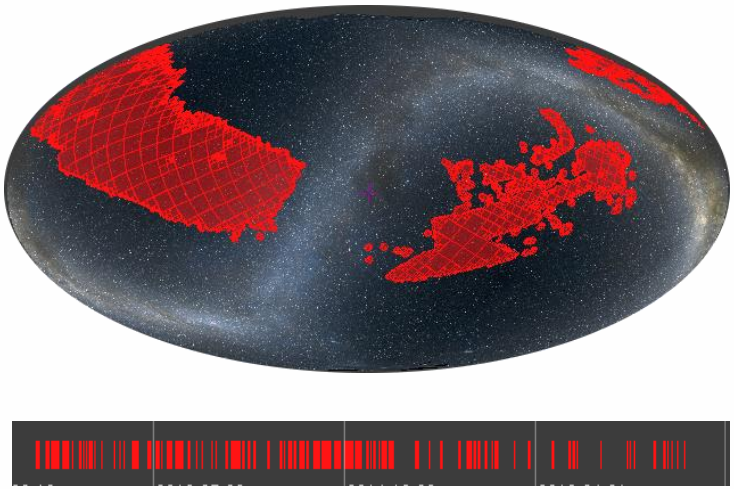

- TMOC conventions:
  - JD(TDB,Barycentric,no offset)
  - Order 29 -> 1 µs TMOC resolution
  - Allow to describe 9133 years from JD=0

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

# When **AND** Where !

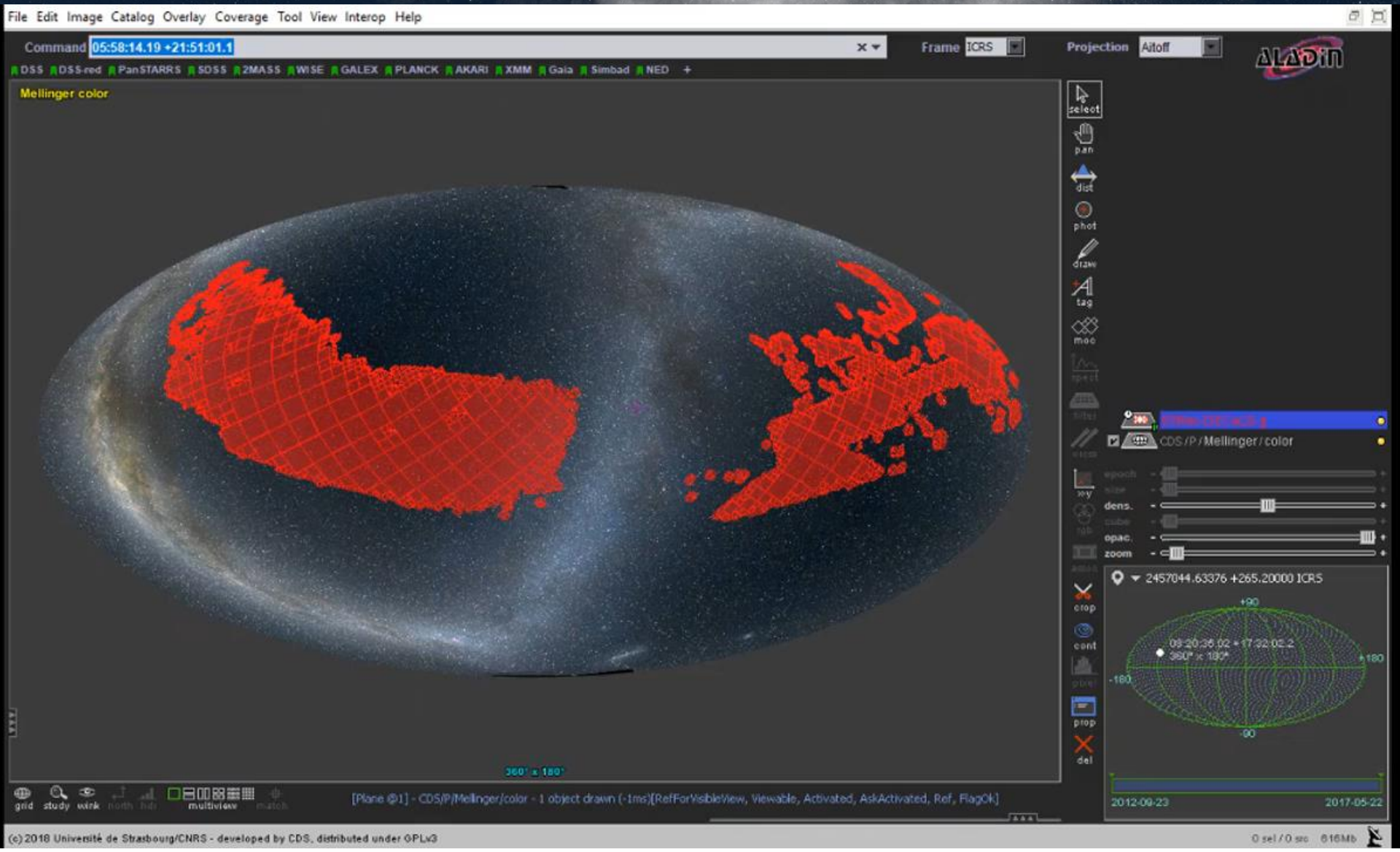
Today

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



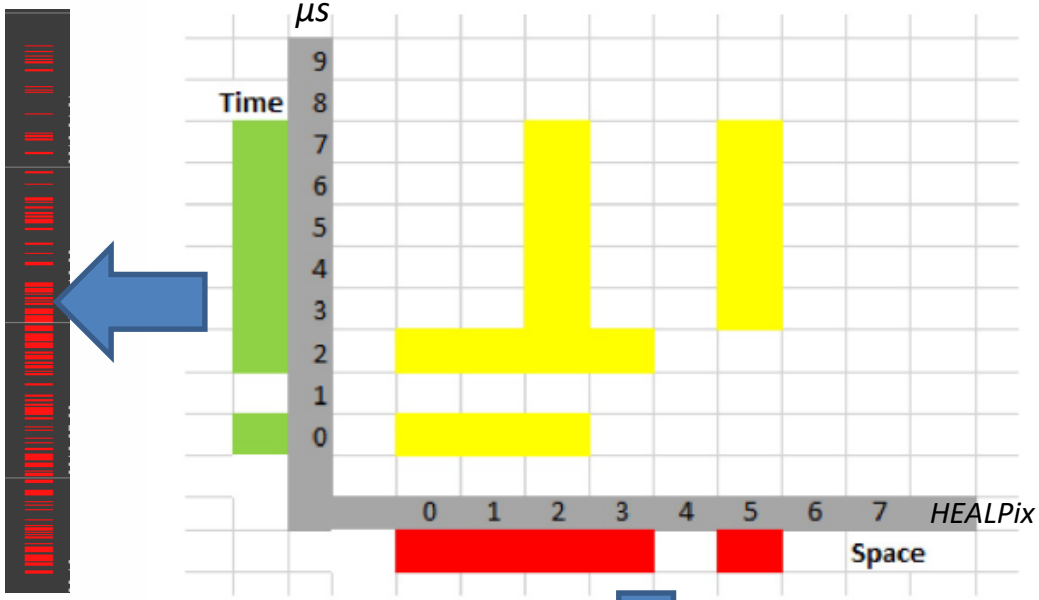
2 years CDS&Co R&D driven by IVOA effort on time

# STMOC live in video



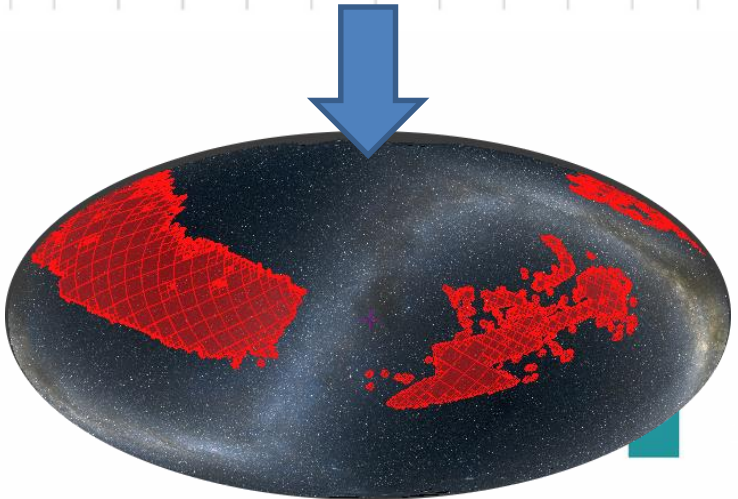
# STMOC concept & challenge

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

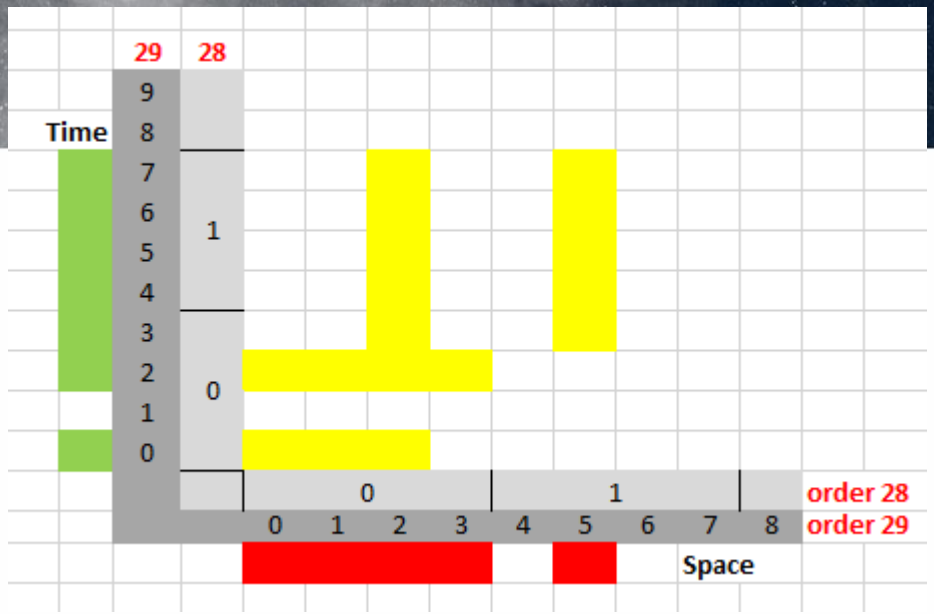



=> The challenge:

**How to describe and manipulate a 2D table efficiently**



# STMOC study

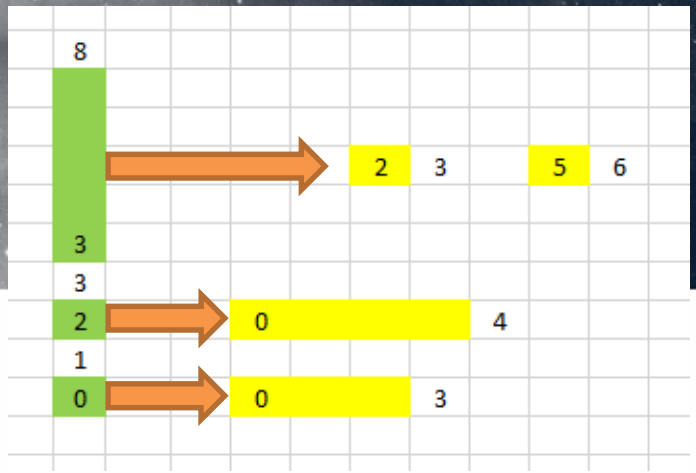



- Existing MOC codings:
  1. List of numbers, hierarchized => MOC
  2. List of ranges at high order => internal usage

$\Rightarrow$ List of indices (ex: 29/0-3,5…)
List of longs (FITS/NUNIQ)

- For STMOC, 2 possible extensions :
  1. Global numbering => but will force to use the same resolution for space and time (=> not a good idea)
  2. **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[, … [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[…[npixminM..npixmaxM[
  - Or list of hierarchical numbers
    order/npix,npix …. order/npix,…

# 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 | 1µs | 393.2µas | 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 |

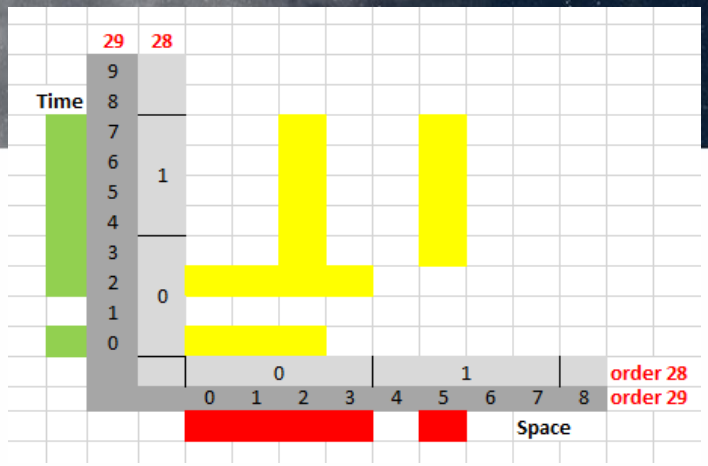
## Saturn ephemerid – 20K positions

| Torder | Sorder | Time resoluation | Space resolution | # time ranges | Size | Time to generate |
|---|---|---|---|---|---|---|
| 29 | 29 | 1µs | 393.2µas | 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:**
  **=>** regulat 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

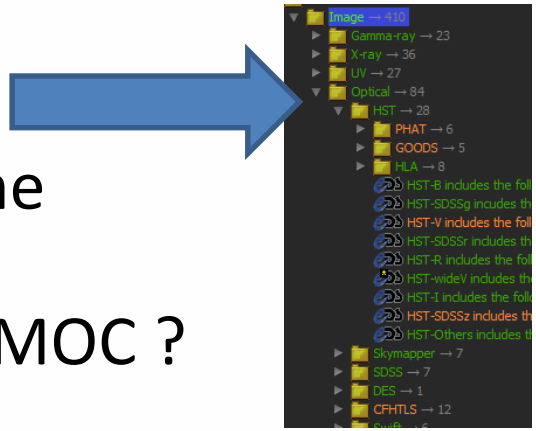
# The live demo…

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:

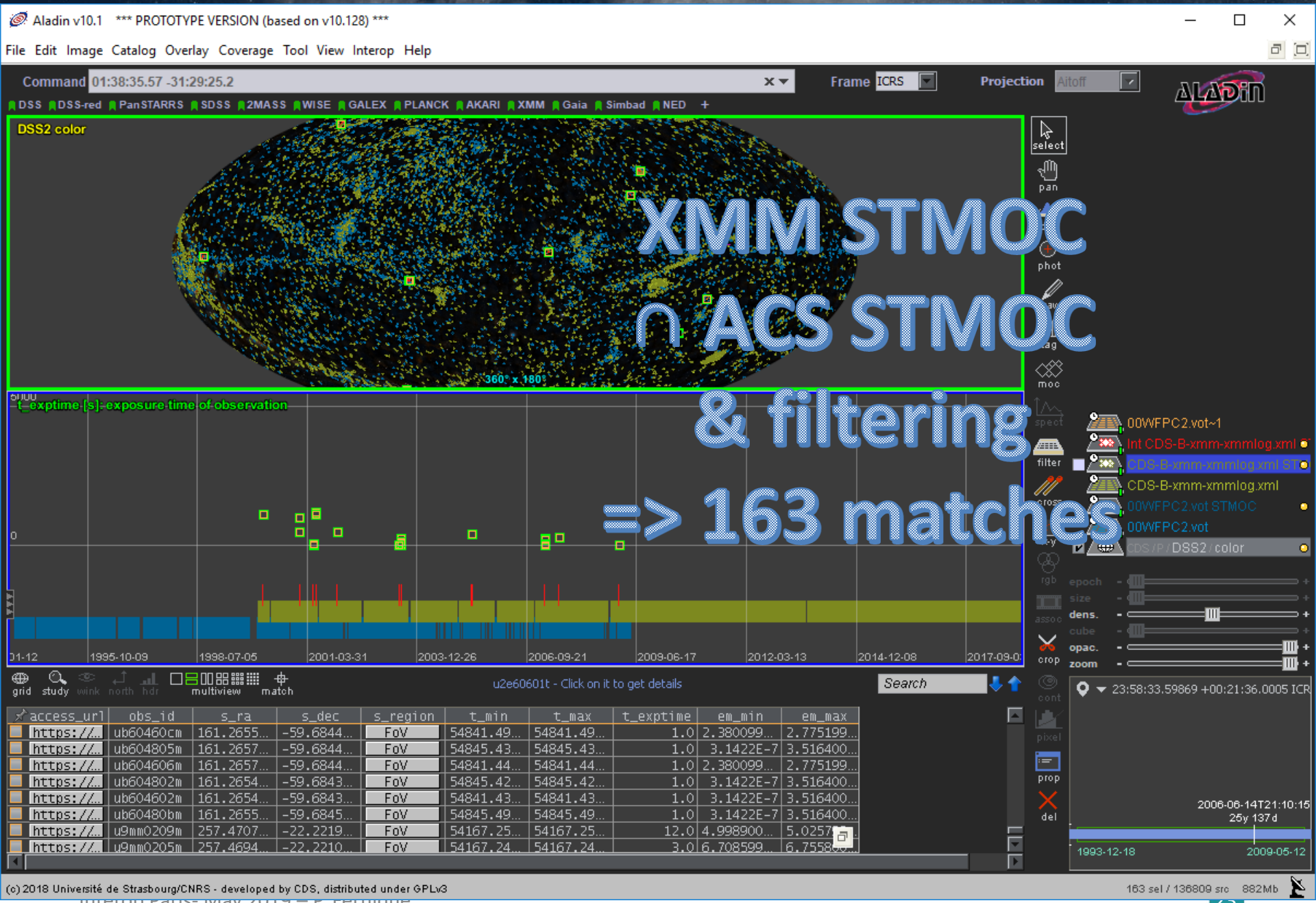
- **Alternate dimension** => ex: **Space-Redshift** MOC
- Or even to introduce a **third dimension**

  => 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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File Edit Image Catalog Overlay Coverage Tool View Interop Help
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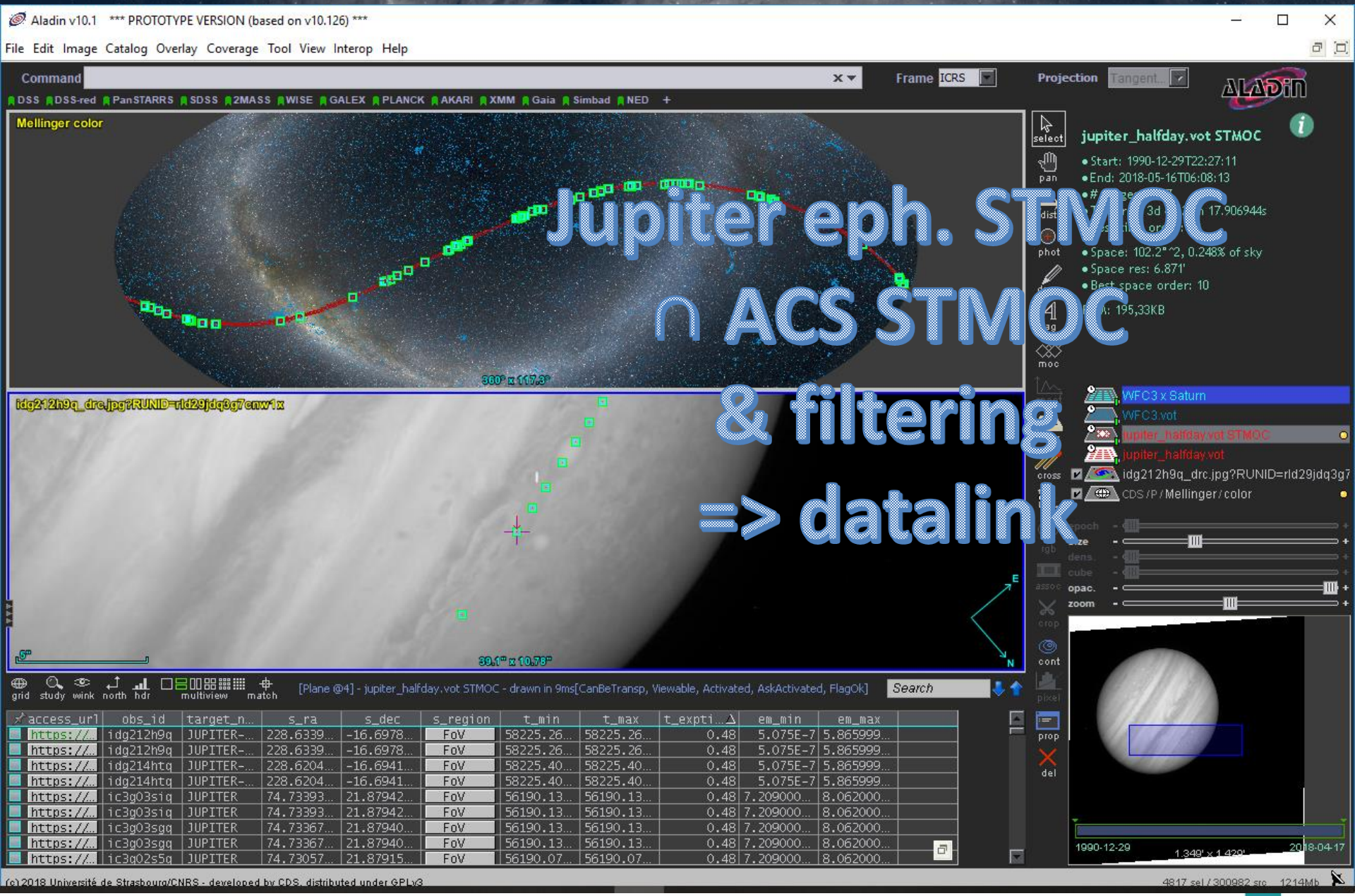
Frame ICRS
Projection Aitoff
DSS DSS-red PanSTARRS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Gaia Simbad NED
DSS2 color
360° x 180°
XMM STMOC
∩ ACS STMOC
& filtering
=> 163 matches
t_exptime [s] : exposure time of observation
1995-10-09
1998-07-05
2001-03-31
2003-12-26
2006-09-21
2009-06-17
2012-03-13
2014-12-08
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
DSS2 color
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
2006-06-14T21:10:15
25y 137d
1993-12-18
2009-05-12
(c) 2018 Université de Strasbourg/CNRS - developed by CDS, distributed under GPLv3
163 sel / 136809 src
882Mb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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_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
WFC3 x Saturn
WFC3.vot
jupiter_halfday.vot STMOC
jupiter_halfday.vot
idg212h9q_drc.jpg?RUNID=rld29jdq3g7
CDS/P/Mellinger/color
Jupiter eph. STMOC
∩ ACS STMOC
& filtering
=> datalink
[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... 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...
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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...
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2018-04-17
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