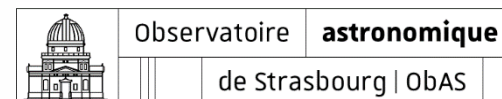


Space Time Coverage by STMOC

ESCAPE TechForum – 4-6 February 2020

Pierre Fernique
and others contributors



□ A few Space-Time use-cases

What is the ESO-VISTA mission coverage in space & time ?

What are the list of catalogs having data for my list of SN detections (time and position) ?



Are there coincidental observations in space and time for XMM and Chandra missions ?

Which observations are available for this gravitational-wave sky localization detected at this epoch ?

□ Time and Space in astronomy

Space and **Time** already the two **main index** of the **astronomical data** centers and archives

But:

- **Heterogeneous** space reference systems (Gal, Eq, ...)
- **Heterogeneous** time reference systems (TDB, TCB, TT, ..)
- **Heterogeneous** DB systems (SQL, TAP, asu...)

=> required **conversions**

=> required multiple syntaxes and translations...

=> Merging results are **complex** and **slow**

□ The challenge behind these use cases

Determine **Where** & **When**
+ in **distributed** and **heterogeneous data**
+ as **fast** as possible

= Manipulation of coverages

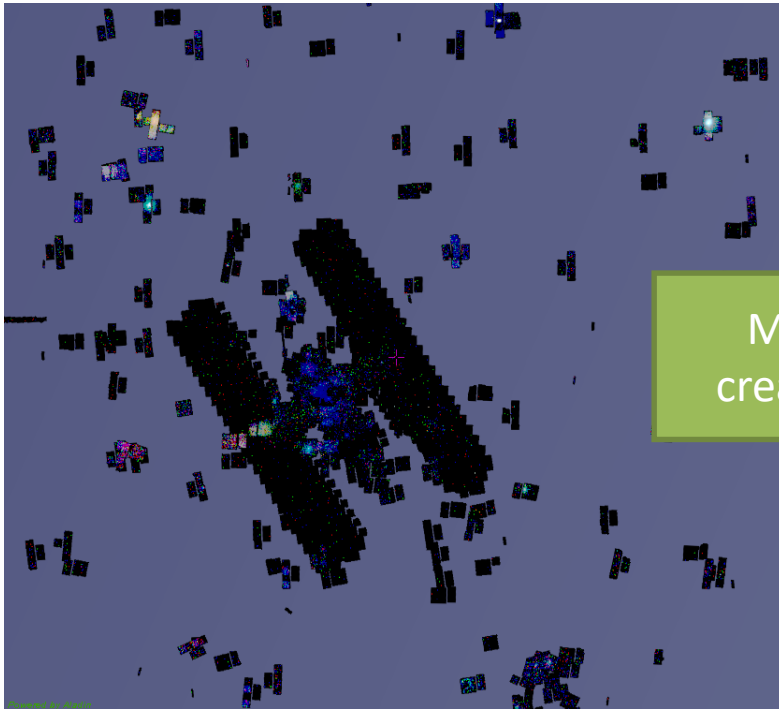
□ We already did it for space

- **MOC** = Multi-Order-Coverage map
- Presented at ADASS 2012 - Urbana
- Standardized in the framework of IVOA in 2014
- Implemented in various tools (Aladin, TOPcat, ...) and already provided by various data providers (Virgo/LIGO, CDS, ...)

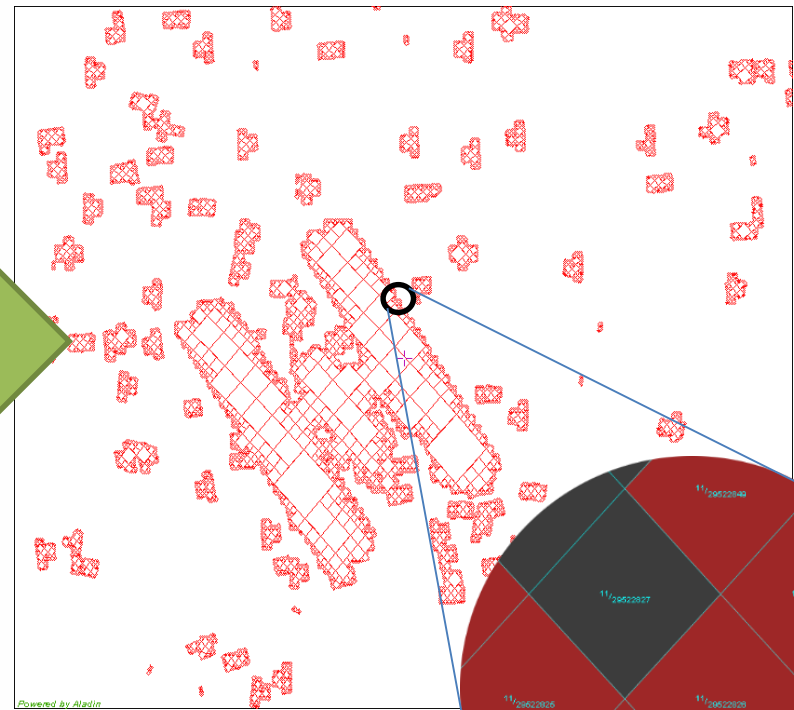
=> That works extremelly well

□ Spatial MOC overview

a **MOC** = a **list of numbers**
based on HEALPix hierarchy tessellation



MOC
creation

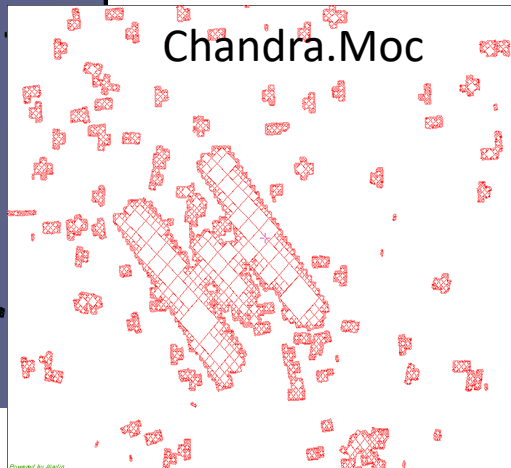
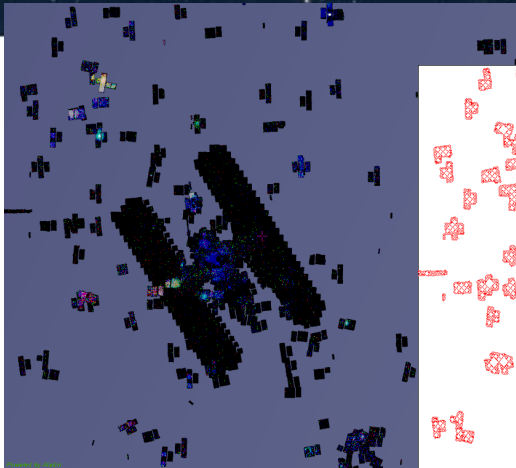


...10/34758...11/29522826 29522848 ...

□ The success keys of MOC

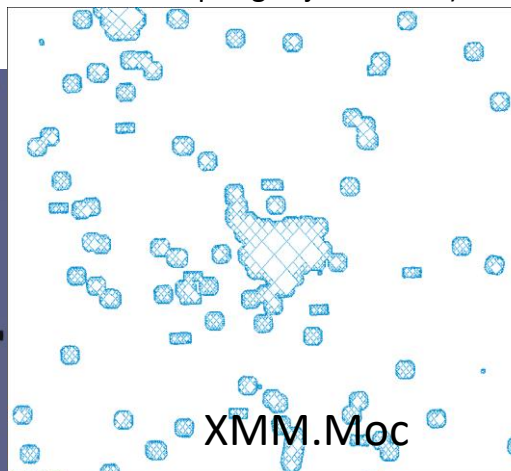
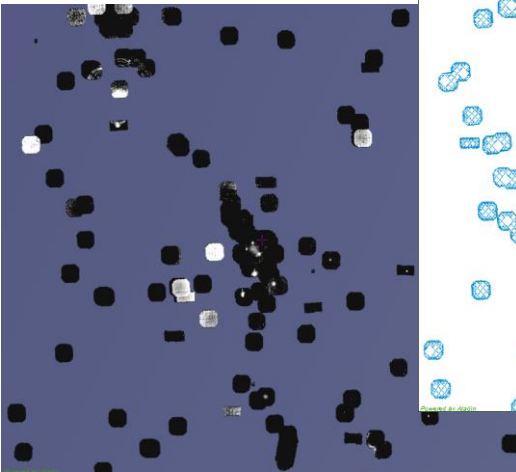
1. **Discretisation** of the space dimension
=> HEALPix
2. A **unique convention** => ICRS
3. **Multi** compatible **resolution** => hierarchical
4. **Canonical representation** => list of integers
5. Simple and **fast basic** operations (intersection, union, complement, subtraction) => a few ms
6. **Basic** syntax and **packaging** => ASCII, FITS

□ MOC in practice



Chandra.Moc

=> **Compact** (by collapsing adjacent cells)



XMM.Moc

=> Operations are extremely **fast** => a few ms

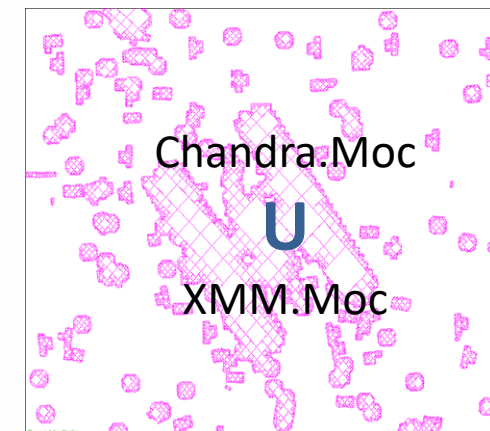
(union, intersection, subtraction, compl)



Chandra.Moc



XMM.Moc



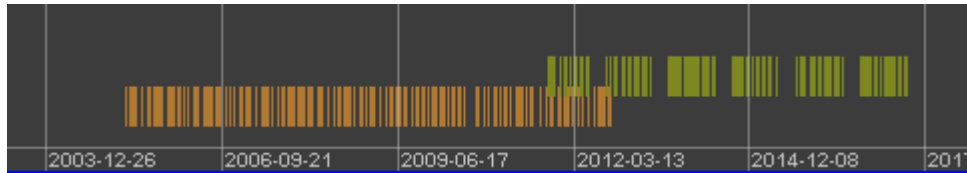
Chandra.Moc



XMM.Moc

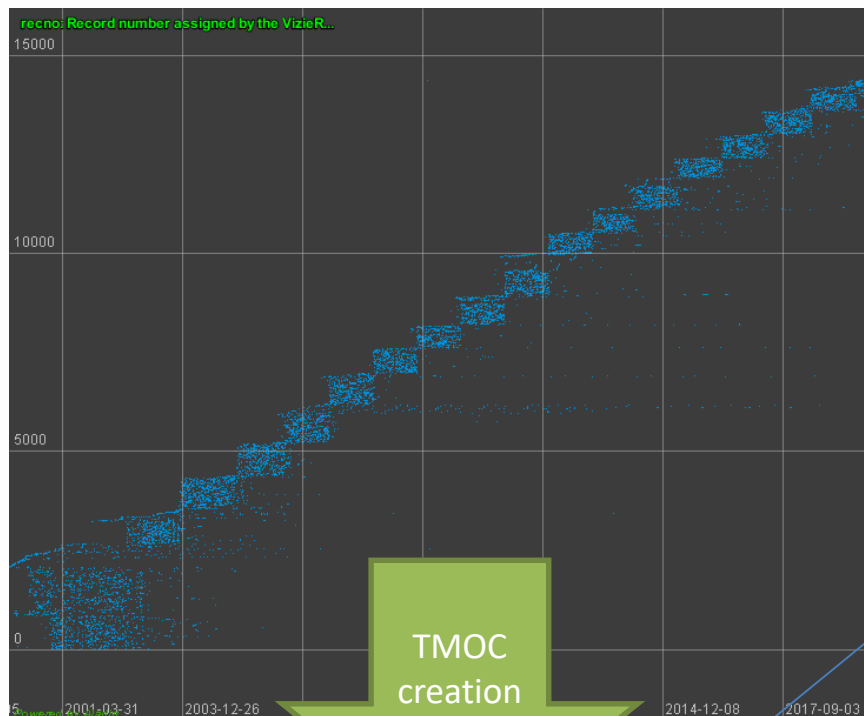
□ Time Coverage => the idea

- *Why not reuse the same winning recipe*
=> **TMOC** = **Time** MultiOrder Coverage
= A list of hierarchical time numbers
- => Just by reusing MOC lib for Time:
 1. Discretisation of the Time dimension
=> **Julian Day division**
 2. A unique convention => **TDB, Barycentric, no offset**



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

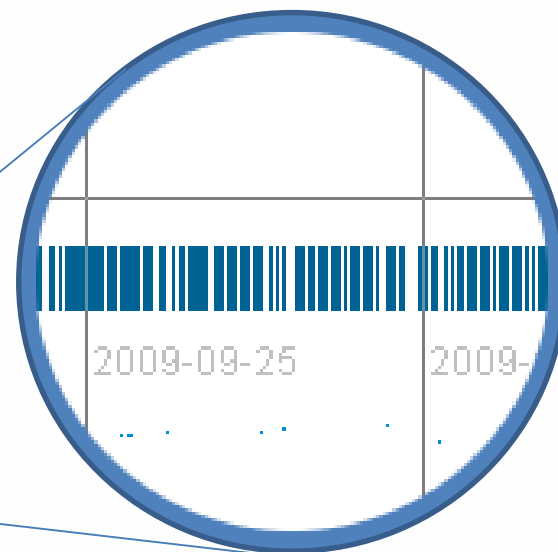
□ Time MOC overview



TMOC
creation



a **TMOC** = a **list of numbers**
based on JD time discretisation



...13/34758...29/295226295248 ...

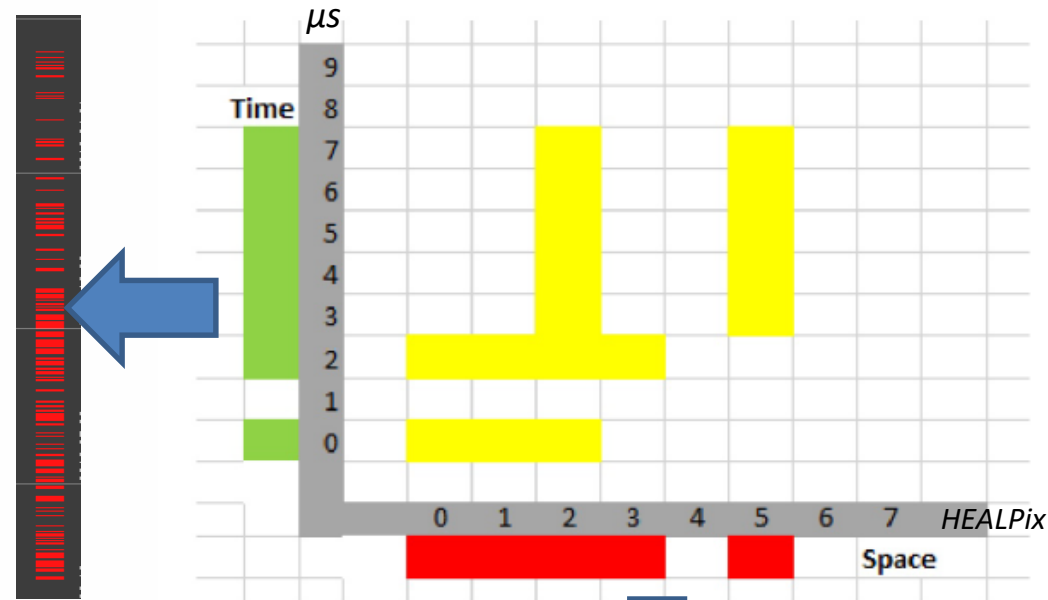
□ When **AND** Where !

- Where **OR** When not enough
=> We need Where **AND** When
- The **STMOC** = **Space Time MultiOrder Coverage**
- Merge together both dimensions in a unique MOC in order to have simultaneously space and time coverage



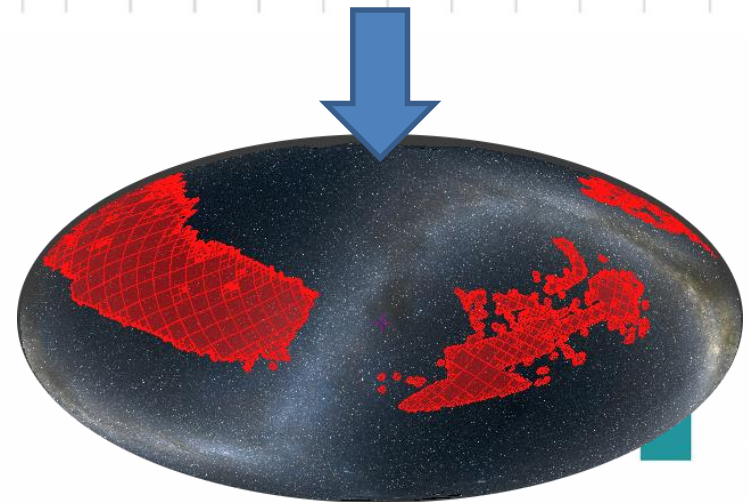
□ STMOC concept & challenge

- (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**

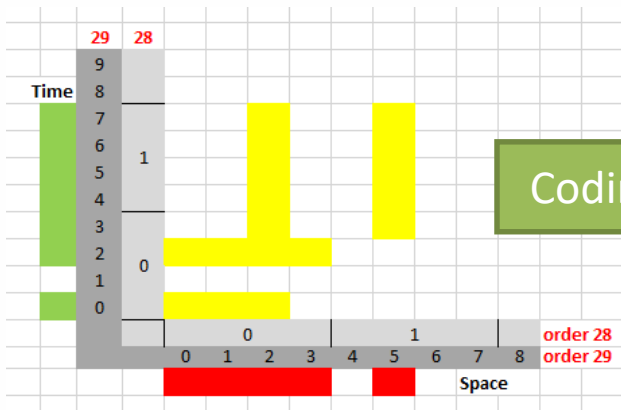


□ STMOC study

How to manipulate efficiently a potentially huge 2D matrix ?

1. *1st try*: Global hierarchical numbering (= MOC 1D)
=> Force to use the same resolution for space and time
=> *not a good idea !*
2. *2nd try*: **Two independent numberings** (= MOC 2D)
=> Time and Space resolutions unattached
+ Coding a la « **Battleship** »

} It's work



Coding

t29/0 s29/0-2
t29/2 s28/0
t28/1 29/3 s29/2 5

packaging

**FITS binary
table**
alternating Time
and Space index

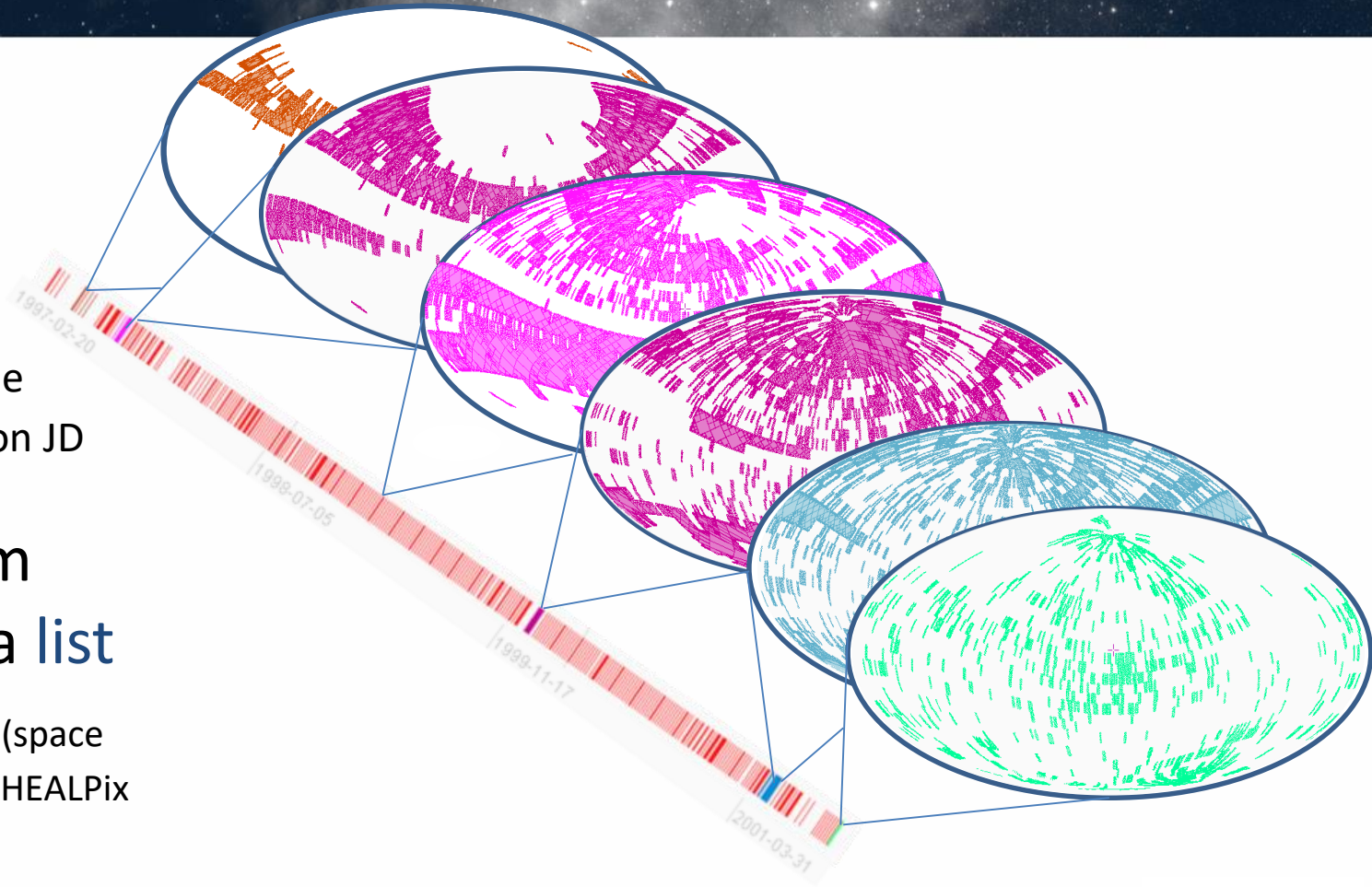
□ Space-Time-MOC overview

a **STMOC**
= a list of
numbers

(time
coverage – based on JD
discretisation)

Each of them
pointing to a list
of numbers

(space
coverage – based on HEALPix
disc.)



...t13/3475 s29/2952295248 ...t13/6389 s28/..

□ 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**
- T-Order 14 (18mn), S-Order 13 (26'') => **0.8s, 1.6MB**

Using FoV,JD

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

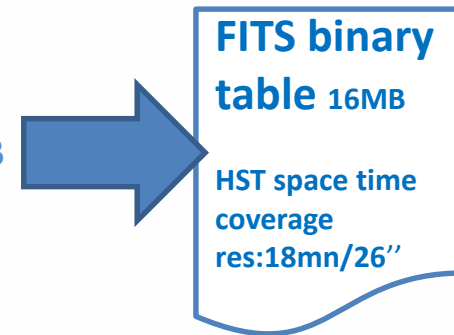
- STMOC **operations**

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

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

- **Filtering** a catalog by STMOC

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



□ Two use cases in live

What is the ESO-VISTA mission coverage in space & time ?

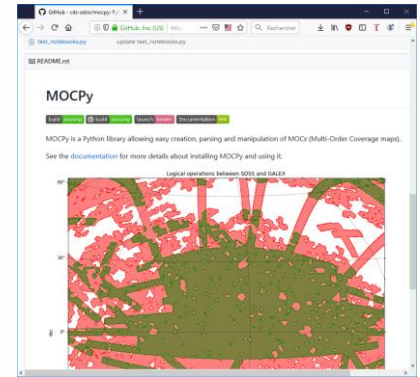
Are there coincidental observations in space and time for XMM and Chandra missions ?



Please in a few seconds...

❑ Creating and using STMOC ?

- **Doc:** IVOA note - May 2019 - Daniel Durand, Pierre Fernique, Ada Nebot, Thomas Boch, Francois-Xavier Pineault
=> <http://www.ivoa.net/documents/stmoc>
- **Tool:** Aladin V11
=> <http://aladin.u-strasbg.fr/AladinV11.jnlp>
- **Python library:** MOCpy (M.Baumann)
=> <https://github.com/cds-astro/mocpy>
- **List of STMOCs** already generated by CDS
=> <http://alasky.u-strasbg.fr/footprints/STMOC>

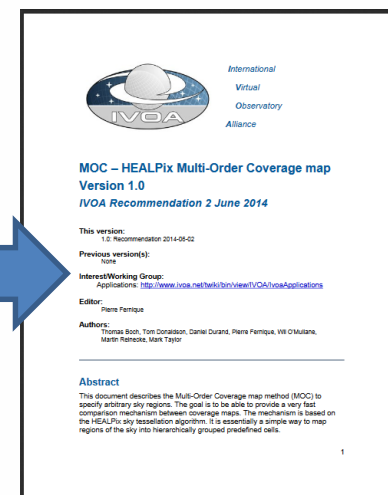
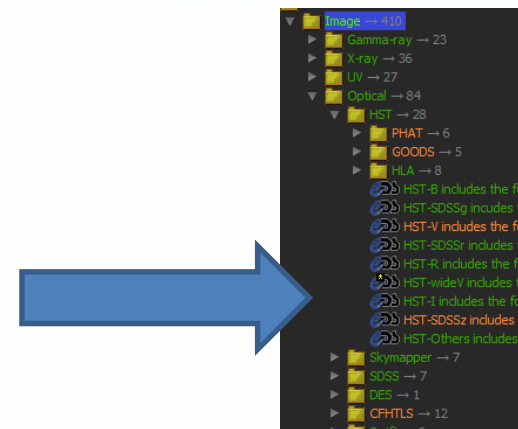


STMOCs

Table ID	Catalogue name	Table name	Records	Time min	Time max
Associated data Ch 37MOC	Associated data for VizieR (G. Landon, 2016)	Visual Spectra images generated as a table	8032403	1970-01-01 00:18:24.08	8579-02-00 08:37:40.03
Chandra Archive Ch 37MOC	The Chandra Archive (CXUC, 1999-04-14)	The Chandra Log (2018-08-22)	12494	1004-04-14 00:44:56.00	2021-02-24 00:01:02.00
General Catalogue of Variable Stars Ch 37MOC	General Catalogue of Variable Stars (Samus', 2007-2013)	Empirical Variable Stars Catalog (Ch 37V)	10979	1885-08-11 15:57:35.92	1999-04-25 12:04:12.03
General Catalogue of Variable Stars Ch 37MOC	General Catalogue of Variable Stars (Samus', 2007-2013)	GCVC catalog (GCVC's 1.1, 1998-March, 2017)	53626	-4711-03-10 11:29:38.00	-4441-02-27 12:20:24.00
Occultation lists Ch 37MOC	Occultation lists (Carruba, Hewat-2016)	White descriptions	4338	1999-06-02 10:12:56.00	2019-07-27 20:18:10.04
Swift lists Ch 37MOC	Swift Monitoring (ASTROSC, 2006-)	SWIFT lists	250682	2005-06-08 23:57:59.93	2019-05-26 00:09:53.08
LAJRO International Variable Star Index Ch 37MOC	LAJRO International Variable Star Index VXX (Wentzel, 2006-2014)	Variable star obs-2V Version 2019-08-23	1123243	1385-01-31 19:36:39.72	2122-03-31 12:08:00.61
XMM-Newton Ch 37MOC	XMM-Newton Observation Log (OMD- Newton Science Team, 2013-08-23)	The XMM-Newton Observation Log (2018-09-23)	14393	2000-04-17 13:26:49.07	2019-09-16 03:39:10.00
Gaia DR1 Ch 37MOC	Gaia DR1 (Gaia, 2016)	Copied data into the catalogue. Visualisation is implemented as "CEP"	398	2014-05-03 20:42:14.10	2014-06-16 01:41:08.99

□ Next steps

- Generated STMOCs
(from **VizieR catalogs**, and **HiPS**)
- Ingested in CDS **MocServer**:
=> Aladin Resource Tree
by Space & Time
- **Renew the IVOA MOC standard**
for supporting TMOC and STMOC
=> IVOA agreed in Nov => **MOC2.0**





Thanks ! Question ?

