

# MOC



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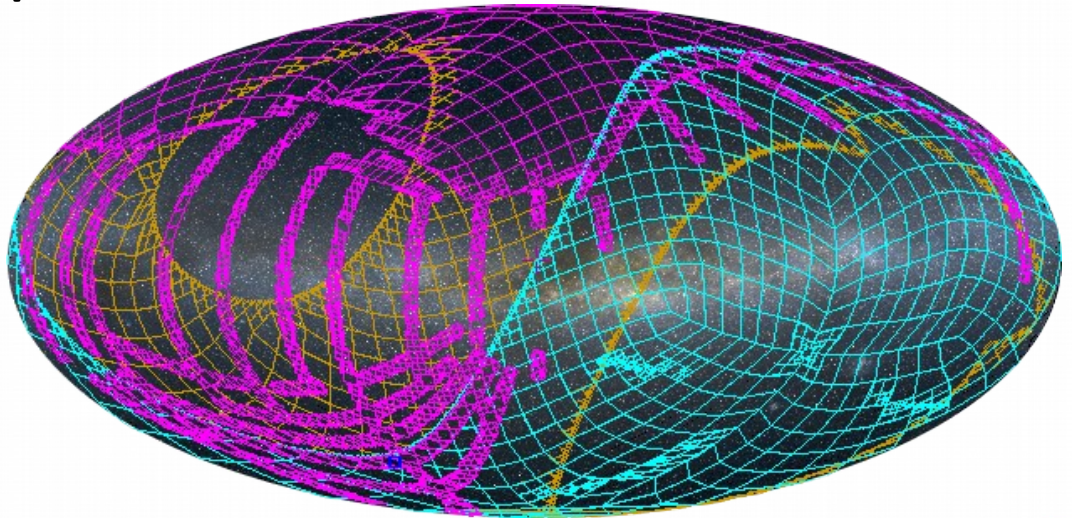


# □ What's the plan ?

1) What is a MOC ?

2) How to create it ? Use it ?

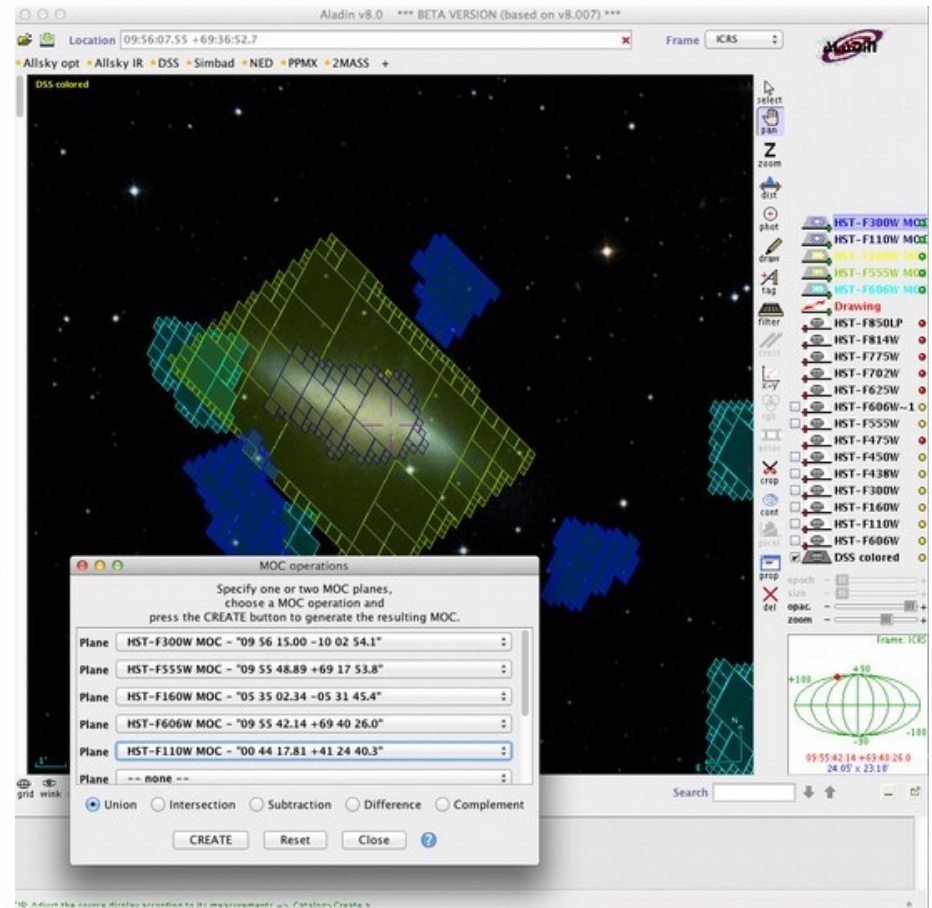
3) The MOC server



# □ MOC – What is it ?

MOC = a generic tool for manipulating sky regions

- Intersection
- Union
- Storing
- Filtering
- Querying



## □ MOC – What is it ?

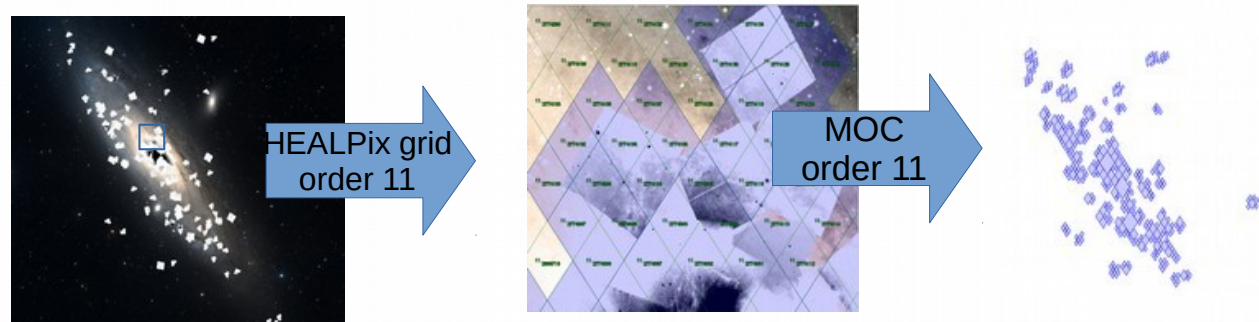
### MultiOrder Coverage map

*“Combine sky regions in few milliseconds”*

- A simple and efficient method to specify any kind of **sky regions**
- Based on **HEALPix** tessellation
- Existing libraries: Java, C, python
- Used in VO tools (Aladin, TOPcat, ...)
- **IVOA Standard** since 2013

# □ The MOC idea

- “Just” the list of HEALPix cell numbers covering a region

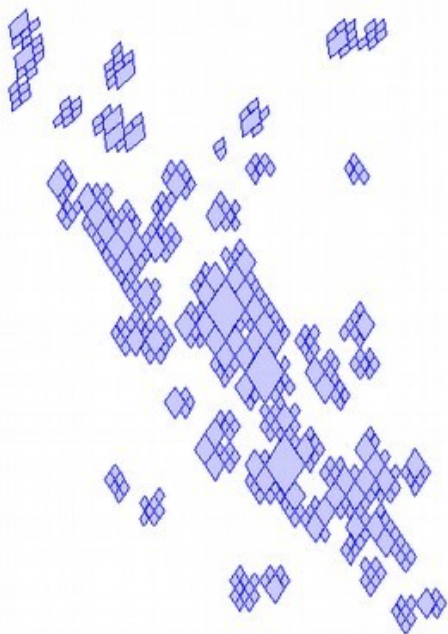


- 4 adjacent cells are replaced by the parent, recursively => intrinsic compression
- Store as a FITS table (or JSON)

```
{"9": [167870, 173376, 173380],  
"10": [671433, 671465, 671467, 671469, 671475, 671478, 671626, 671627, 671642, 671649, 671659, 671663, 671669, 671674, 671675,  
671676, 671690, 671715, 671719, 671725, 671726, 671730, 671731, 671734, 671735, 671736, 682657, 682721, 682725, 693076,  
693251, 693267, 693269, 693270, 693279, 693302, 693313, 693314, 693315, 693320, 693322, 693323, 693328, 693332, 693339,  
693342, 693371, 693508, 693509, 693510, 693513, 693516, 693517, 693524, 693526, 693528, 693529, 693531, 693578, 693581,  
693591, 693614, 693732, 704512, 704513, 704519],  
"11": [2685615, 2685626, 2685627, 2685673, 2685675, 2685676, 2685678, 2685679, 2685689, 2685691, 2685692, 2685694, 2685713, 2685714, 2685715,  
2685716, 2685718, 2685719, 2685720, 2685721, 2685723, 2685724, 2685725, 2685740, 2685741, 2685744, 2685746, 2685851, 2685854, 2685855,  
2685859, 2685872, 2685873, 2685874, 2685880, 2685894, 2685895, 2685897, 2685898, 2685899, 2685906, 2685909, 2685911, 2685936, 2685945,  
2685946, 2685947, 2685948, 2685950, 2685951, 2686110, 2686125, 2686128, 2686130, 2686131, 2686136, 2686138, 2686154, 2686155, 2686158
```

# □ MOC accuracy

- Depends of the MOC **order**  
= the smallest HEALPix cell level used in the MOC

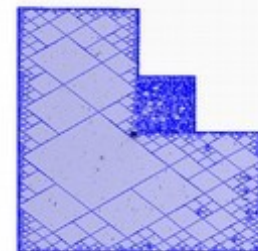


Order **11**  
=>1.718 arcsec



Order **20**  
=>201.3mas

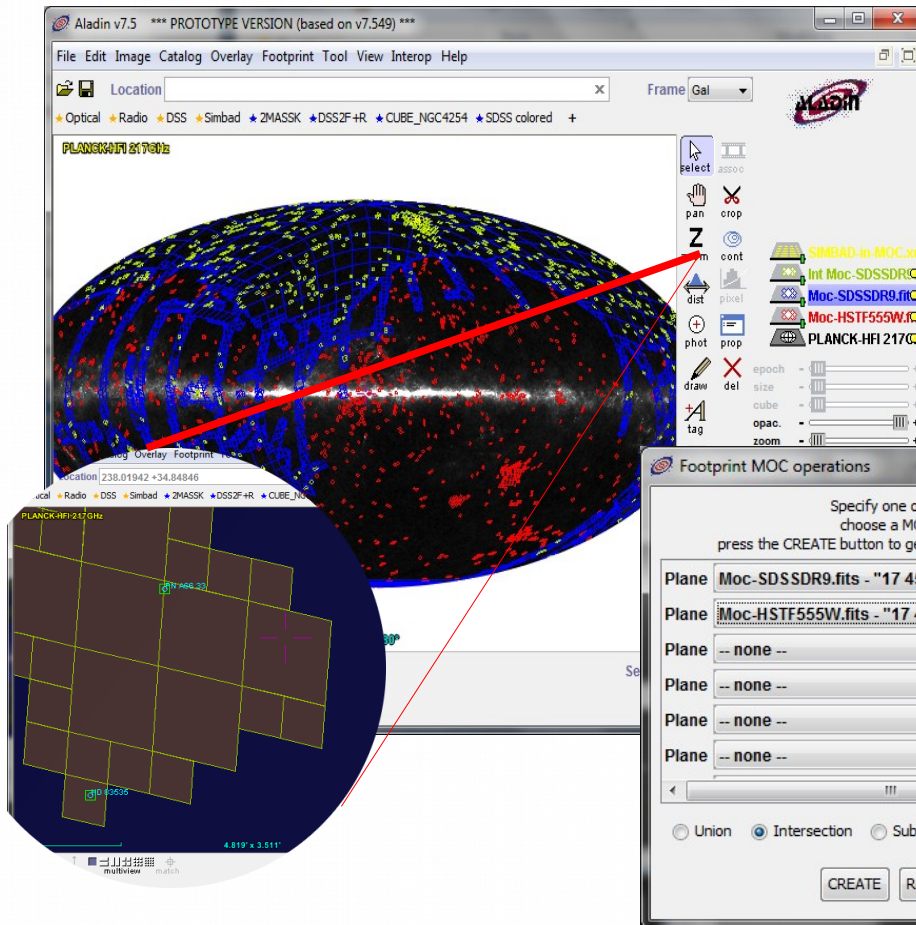
• • •



Order **29**  
=>391  $\mu$ s

# □ MOC – Use case

*“Get all Simbad objects for which there are both HST and SDSS observations ?”*



1. Load  
MOC-HST  
MOC-SDSS
  2. Compute  
MOC intersection
  3. Query Simbad by MOC
- => Realized in 5s

# □ MOC – Use case

“MOC for describing the gravitational wavelength origin region”

The GCN Circular (18858) shows the overlap regions between the sky maps published with the GW 150914. The same regions are visualized applying the MOC method.

Both of the sky maps above agree with the initial LALInference result to the local location: `sky000_120_skymap.fits.gz` on the southern portion of the annulus delineated by an arrival time difference between LIGO Hanford and LIGO Livingston of about 7 ms.

The table below presents a quantitative comparison of the available localizations along the lines of Sec. 4.5 of Bacon et al. (2015), <http://dx.doi.org/10.1088/0004-6370/792/1/1>. The first column gives the area in  $\text{deg}^2$  of the 90% credible region, and the second column gives the area in  $\text{deg}^2$  of the overlap with the LALInference 90% credible region.

| Area | Overlap | Algorithm           | Filename                  |
|------|---------|---------------------|---------------------------|
| 150  | 276     | 90% Credible Region | sky000_120_skymap.fits.gz |
| 750  | 276     | LALInference        | sky000_120_skymap.fits.gz |
| 400  | 276     | LALInference        | sky000_120_skymap.fits.gz |
| 900  | 276     | LALInference        | sky000_120_skymap.fits.gz |

The slide also features three sky map visualizations showing the overlap regions between the sky maps published with the GW 150914 and the MOC method. A blue arrow points from the text to the visualizations. The slide is part of a Prezi presentation titled "Meeting with Euro-VO May 31-Jun 1st" by Greco Giuseppe, dated June 1, 2016.



## □ The 4 MOC principles (in an ideal world)

- **Simplicity**: Just a table of numbers – no spherical computations in MOC lib.
- **Efficiency**: extremely fast, quite compact
- **Versatility**: Can be used for a rough description, or an accuracy description...
- **Compatibility**: Healpix based

## □ The MOC server

*“What & where in a few milliseconds”*

- **Idea:** store several MOCs in a unique server
- In order to answer to these kind of questions:
  - *Which data collections are localized in this sky region ?*
  - *What is their coverage ?*

## □ The MOC server: in details

- A Tomcat servlet at CDS (just 3 000 java line code)
- Containing **thousands of MOCs** in RAM
- Queryable by region (circle, polygon or MOC) via HTTP GET or POST
- Provides **the ID list** of the data set found in the region...
- ...Or the **union** - resp. the **intersection** – of **the datasets MOCs** (format : FITS or JSON)

## □ The MOC server: metadata extension

- **Idea:** extend the MocServer contents with some properties associated to each data set (title, description, keywords, etc)
- MOC server becomes **a extremely fast and powerful meta-data server**, spatially indexed.

# □ The MOC server: examples

<http://alaska.unistra.fr/MocServer/query>

**5 ms** IDs of all data sets in 5 deg around M31:  
=> ...? RA=10.68 & DEC=41.273 & SR=5

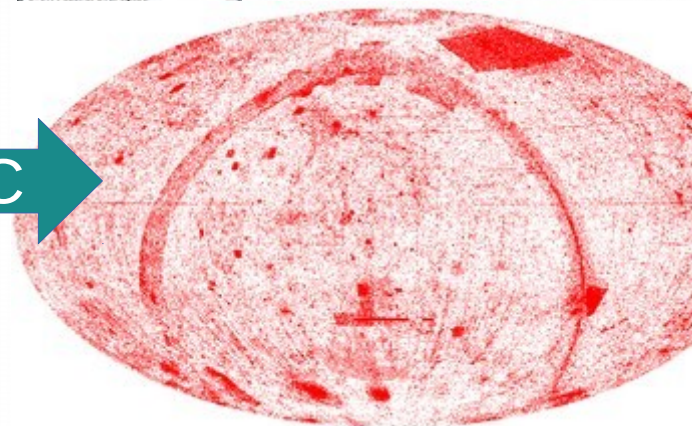
IDs

**21 ms** IDs of HST collections overlapping SDSS obs:  
=> ...? ivorn=\*HST\* & url=http://urlMocSDSS

**492 ms**  
**731 tables** MOC union of all A&AS tables:  
=> ... ? ivorn=CDS/J/A+AS/\* & get=moc

**44 ms**  
**46 cats** MOC union of all Seyfert data sets  
=> ...? obs\_astronomy\_kw=Seyfert\* & get=moc

MOC

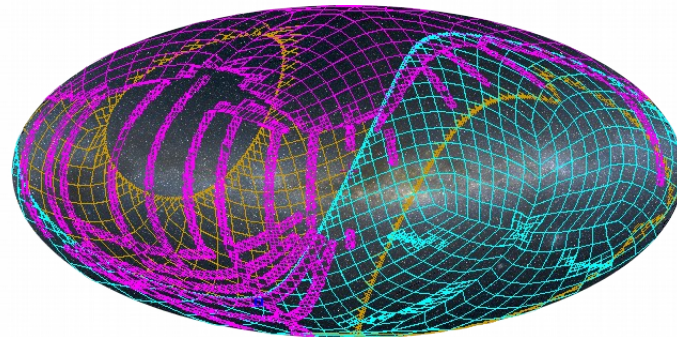


## □ The MOC server: for whom ?

- The **MocServer is dedicated to any remote clients.**
- Its speed allows to implement dynamic interfaces.
- It contains all Vizier tables MOCs, Simbad MOC, and HiPS MOCs (16 279 data set MOCs)
- It is already **in use by Aladin** Lite and Aladin Desktop for continuously displaying the data set list concerned by the current user view.
- A stress test has demonstrated that it fully supports several millions queries per day.

# □ MOC hands-on

**MOC! You said MOC?! (15mn)**



Thanks !  
Questions ?

