

Exploring large catalogues with HiPS and MOCs



ESCAPE 2nd VO school

CDS team



□ What is HiPS ?

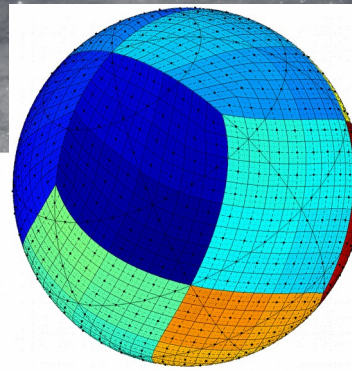
- **Hierarchical Progressive Survey**

"The more you zoom in on a particular area, the more details show up"

- Multi-resolution **HEALPix** data structure for **Images**, **Catalogues**, 3-dimensional data **cubes**, ...
- Conserves scientific data properties alongside visualisation considerations
- No databases or servers, just HTTP

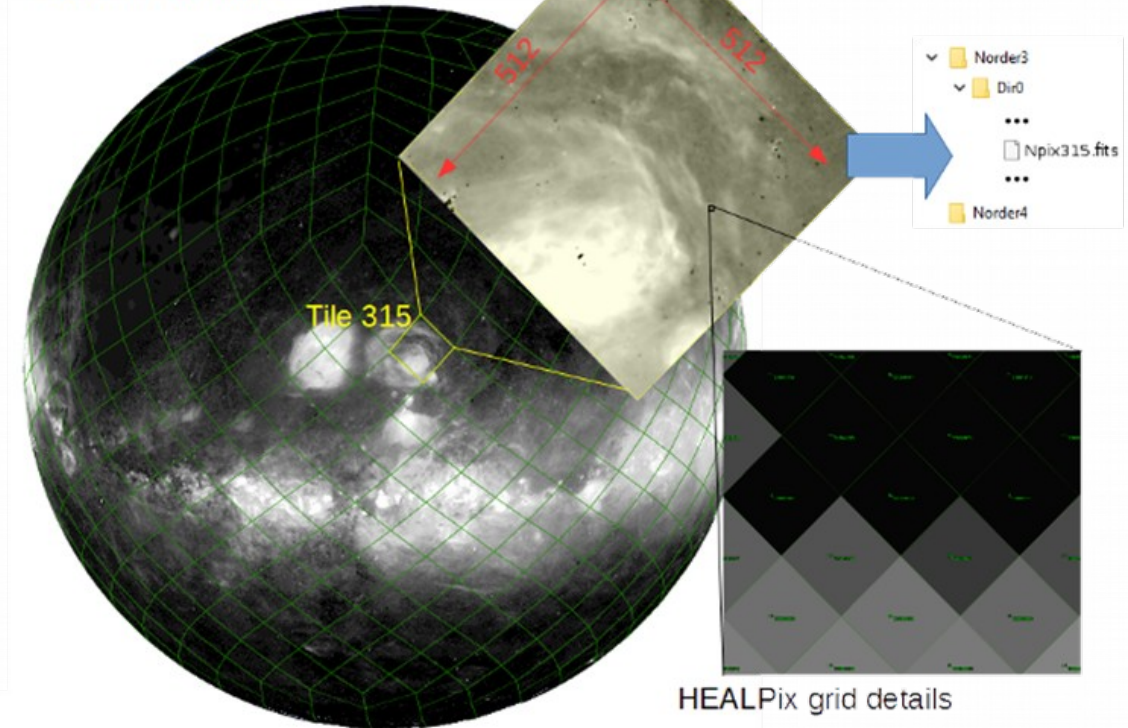


□ What is HiPS ?



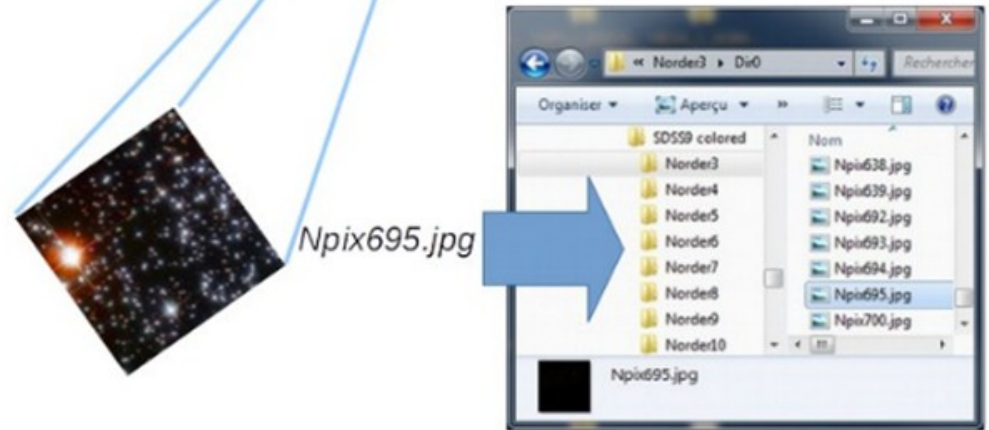
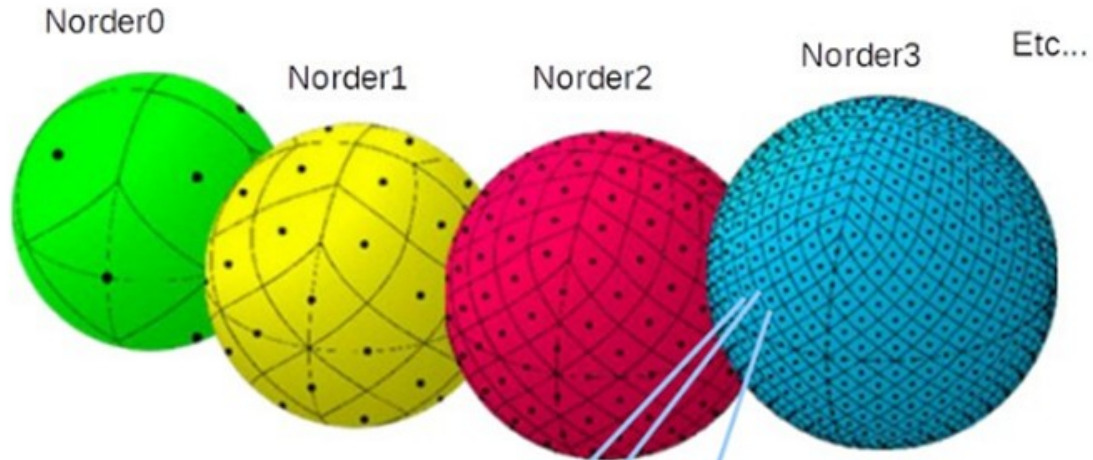
- HEALPix (Gorski et al. 2005)
 - 12 quadrilateral pixels
 - 2x2 division at each level
 - Equal area, Iso-latitude
- HiPS = Mosaic of HEALPix tiles (HEALPix pixel geometry)

HiPS (Halpna Finkbeiner)
order 3 = 768 tiles



□ What is HiPS ?

- HiPS =
Collection of
tiles as files.



□ Different kinds of HiPS

- HiPS images : progressive image survey
 - HiPS nodes contain FITS (full pixel dynamics), JPG or PNG (used for web browsing / Aladin Lite) tiles : images at different resolutions
- HiPS cubes
 - 3D datasets : 2 spatial dimensions + 1 other
 - For example radio frequencies, spectral cube (MUSE, ...)
- HiPS catalogues
 - Progressive catalogue display, useful for very large catalogues
 - Associate a « score » to each source, and sort by score (could be brightness, distance, number of citations, ...)
 - Store sources with highest scores in top-level nodes ; sources with lower scores are associated to nodes deeper in the hierarchy

□ What is MOC ? → sky « footprint »

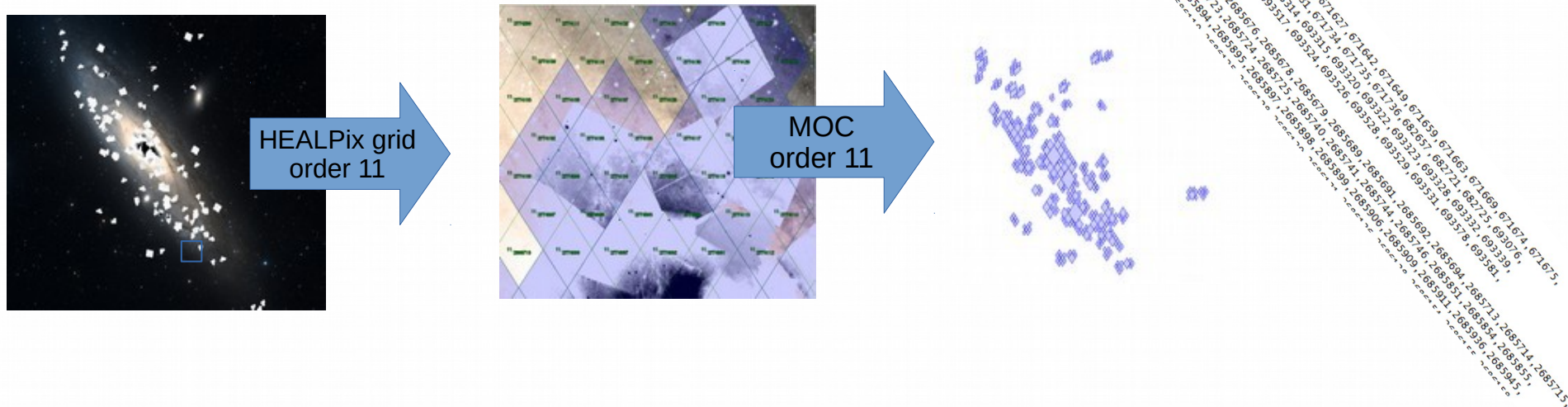
- **Multi-Order Coverage map**

“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, ...)

❑ What is MOC ?

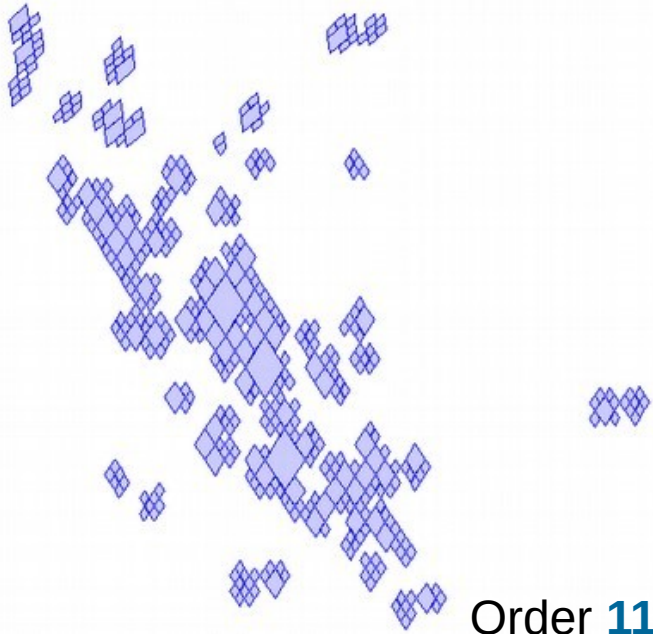
- “Just” the list of HEALPix cell numbers covering a region



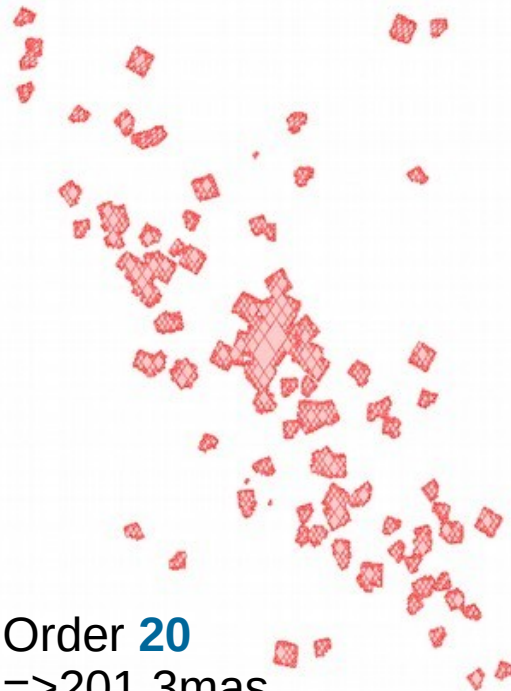
- 4 adjacent cells are replaced by the parent, recursively
→ intrinsic compression
- Store as a FITS table (or JSON)

□ What is MOC ?

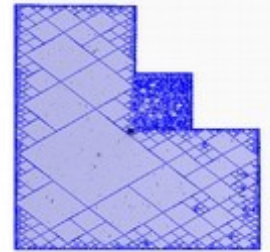
- MOC accuracy depends of the MOC **order**
= the smallest HEALPix cell level used in the MOC



Order **11**
=>1.718 arcsec



Order **20**
=>201.3mas



Order **29**
=>391 μ s

...

IVOA standards



Version 1.0
IVOA Recommendation
19th May 2017

This version:
1.0: Recommendation 2017-05-19

Previous version(s):
1.0: Proposed Recommendation 2017-04-06
1.0: Proposed Recommendation 2017-04-03
1.0: Proposed Recommendation 2017-02-07
1.0: Proposed Recommendation 2016-11-22
1.0: Working Draft 2016-06-23

Interest/Working Group:
Applications: <http://www.ivoa.net/wiki/bin/view/IVOA/IvoaApplications>

Editor:
Pierre Fernique

Authors:
Pierre Fernique, Mark Allen, Thomas Boch, Tom Donaldson, Daniel Durand,
Ken Ebisawa, Laurent Michel, Jesus Salgado, Felix Stoehr

Abstract

This document presents HiPS, a hierarchical scheme for the description, storage and access of sky survey data. The system is based on hierarchical tiling of sky regions at finer and finer spatial resolution which facilitates a progressive view of a survey, and supports multi-resolution zooming and



MOC: Multi-Order Coverage map
Version 2.0

IVOA Proposed Recommendation 2022-01-25
Working group
Applications

This version:
<http://www.ivoa.net/documents/moc/20220125>

Latest version:
<http://www.ivoa.net/documents/moc>

Previous versions:
Version 1.1
Version 1.0

Author(s)

Pierre Fernique (CDS), Ada Nebot (CDS), Daniel Durand (CADC),
Matthieu Baumann (CDS), Thomas Boch (CDS), Giuseppe Greco
(EGO-Virgo), Tom Donaldson (STScI/NASA), Francois-Xavier
Pineau (CDS), Mark Taylor (University of Bristol), Wil O'Mullane
(Vera C. Rubin Observatory), Martin Reinecke (Max Planck),
Sébastien Derrière (CDS)

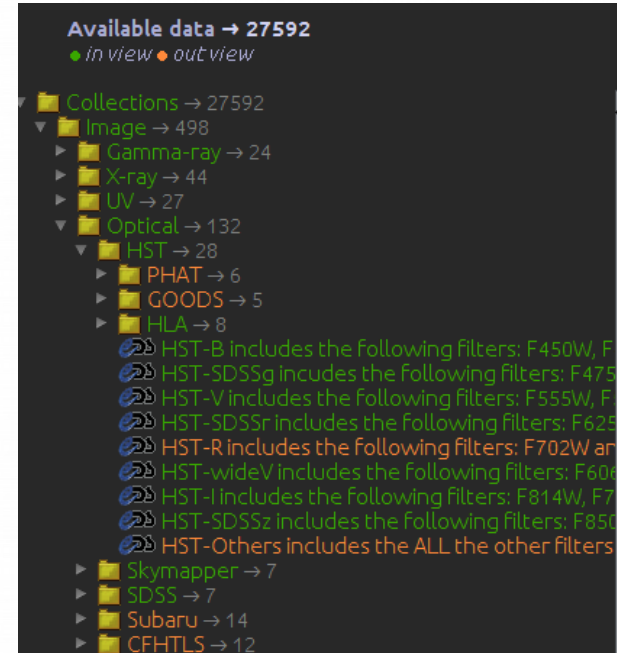
Editor(s)

Pierre Fernique, Ada Nebot, Daniel Durand

T
S
C
O
the
reg

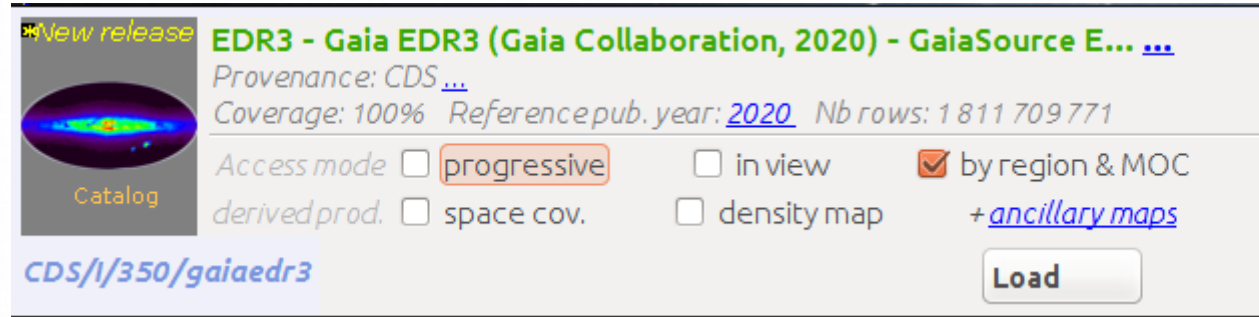
□ Usage of HiPS and MOCs

- Browse very large datasets without downloading the full data
 - PanSTARRS 1 band = 15TB
 - Gaia EDR3 1.8 billion sources
- MOC gives you a boolean value for sky coverage
 - See Aladin Data collections tree : orange/green colours
- Compute logical operations on coverage : intersection, union
 - What region of the sky is observed by SDSS, Gaia and HST in the V band ?
- Create your own HiPS and MOCs
 - Hipsgen <https://aladin.u-strasbg.fr/hips/HipsIn10Steps.gml>



□ Usage of HiPS and MOCs

- Query catalogue by MOC
- Programmatic use
 - Mocpy <https://github.com/cds-astro/mocpy>
- Soon : new standard with STMOC : combined space-time coverage



The screenshot shows the CDS Gaia EDR3 query interface. On the left, there is a thumbnail of a galaxy with the word "Catalog" below it. To the right of the thumbnail, the text "EDR3 - Gaia EDR3 (Gaia Collaboration, 2020) - GaiaSource E..." is displayed in green. Below this, the provenance is listed as "CDS ...". The coverage is "100%" and the reference publication year is "2020". The number of rows is "1 811 709 771". The access mode is set to "progressive" (highlighted with a red box). Other options include "in view", "by region & MOC" (checked), "density map", and "space cov.". A link for "+ ancillary maps" is also present. At the bottom left, the URL "CDS/l/350/gaiaedr3" is shown. A "Load" button is located at the bottom right.

[View release](#) **EDR3 - Gaia EDR3 (Gaia Collaboration, 2020) - GaiaSource E...** ...
Provenance: CDS ...
Coverage: 100% Reference pub. year: [2020](#) Nb rows: 1 811 709 771
Access mode ☐ **progressive** ☐ in view ☒ by region & MOC
derived prod. ☐ space cov. ☐ density map + [ancillary maps](#)
[CDS/l/350/gaiaedr3](#) **Load**

□ Tutorial outline

1. Retrieve a sample of FITS images
2. Create the MOC for these images
3. Logical operations on spatial MOCs
4. Query catalogues by MOC
5. Cross-matching and analysis

□ Tutorial

- Let's see this in practice !

