HIPS3D and MOCs Progress Report

Görlitz – IVOA Interop Oct 2025

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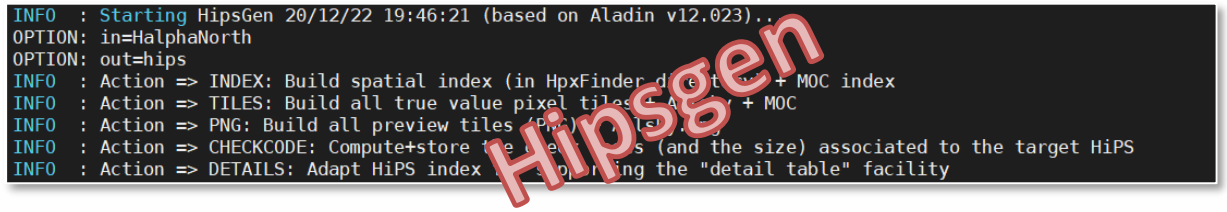
HiPS3D tools before summer

June 2024

12 months

June 2025

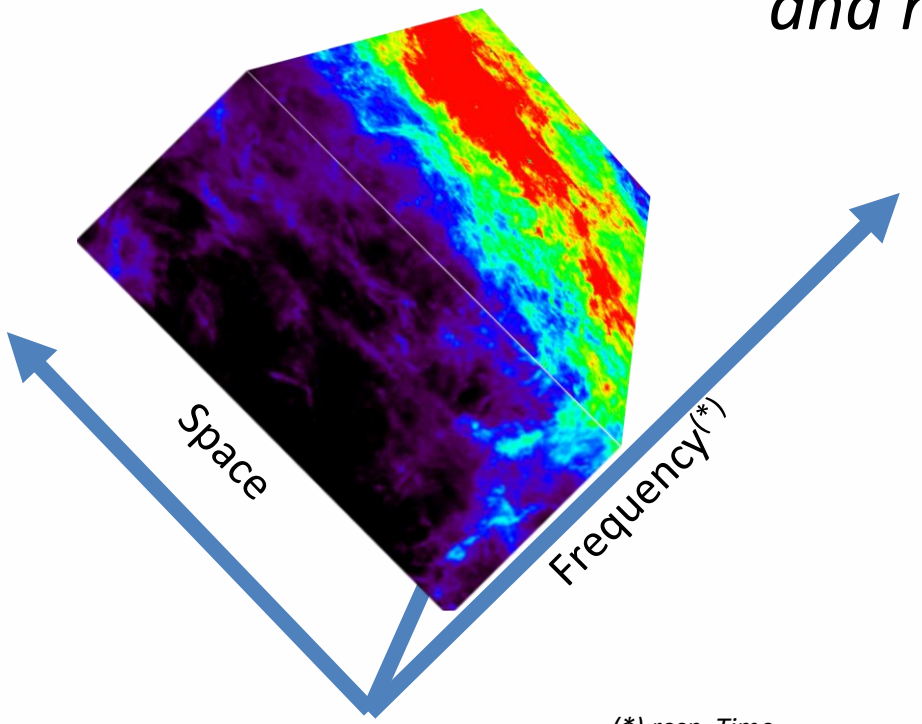


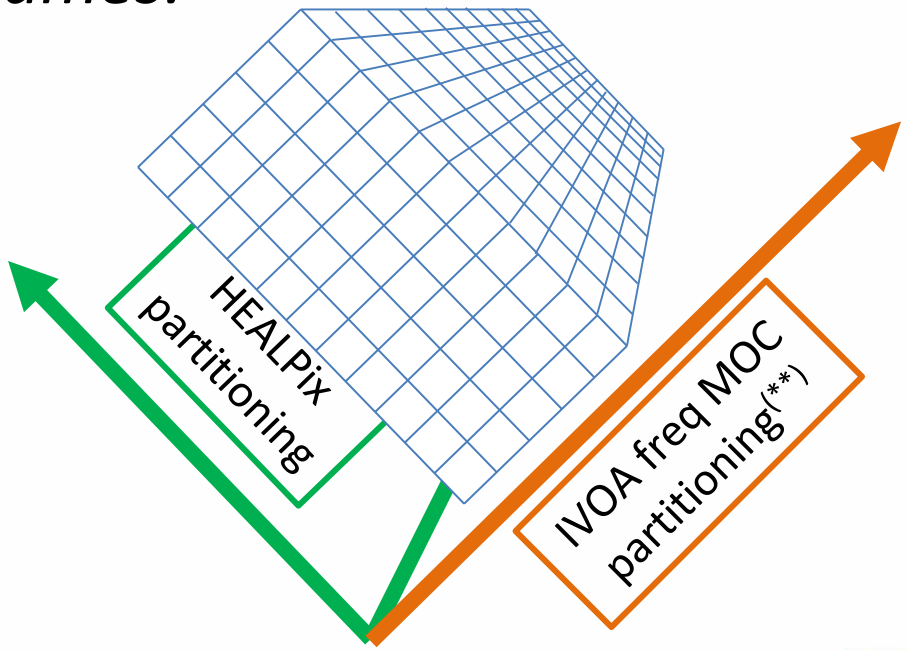
- **Hipsgen**: HiPS generation (prototype)
- **Aladin Desktop:** Standalone HiPS visualization (prototype)

HiPS3D idea reminder

*Extend the current HiPS towards a **HiPS 3D***

i.e. *use a **hierarchical partition in each physical dimension***
and based on absolute physical units
and reference frames.



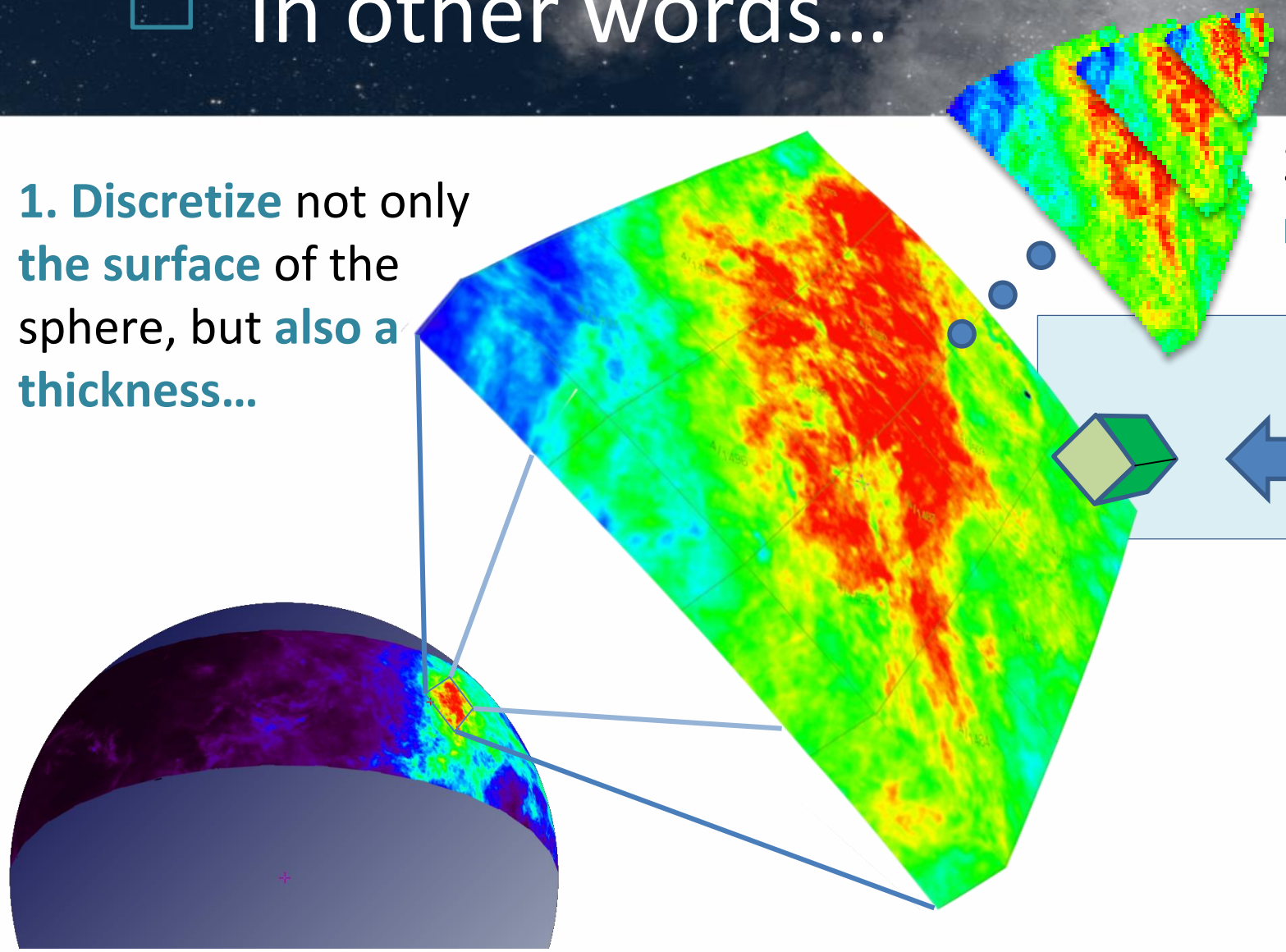


(*) resp. Time

(**) based on IVOA MOC 2.0 & frequency extensions

In other words…

1. Discretize not only **the surface** of the sphere, but **also a thickness…**



2. And do this at **several resolutions**

Each 3D pixel in the pyramid has a unique HiPS3D address:

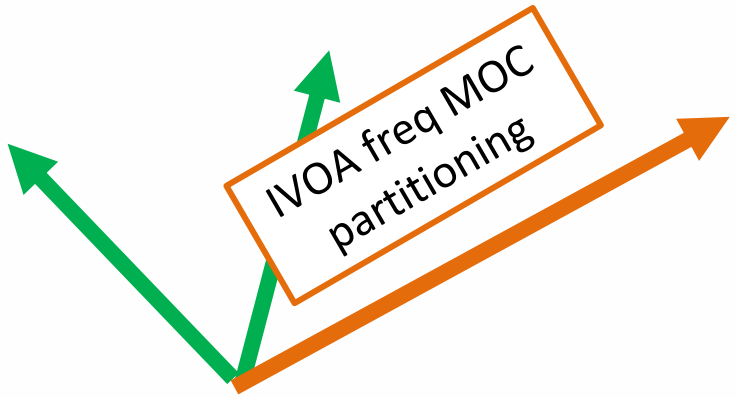
(OrderS/NpixS_OrderF/NpixF)

HEALPix partitioning

IVOA freq MOC partitioning

https://aladin.cds.unistra.fr/java/DocTechHiPS3Den.pdf

IVOA frequency MOC: Where are we ?



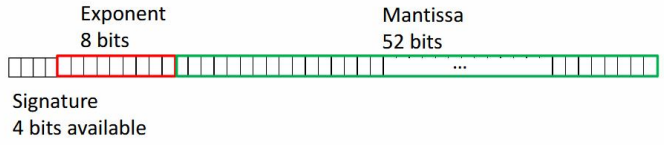
The challenges

- **Reminder**: The MOC only handles **64-bit integer** lists
  - Space: HEALpix indices
  - Time : JD in µs for time
  - Energy : ??
- **Constraints**
  - Amplitude large enough to describe the observations
  - Good accuracy whatever the regime
- **Energy**
  - Difficult to code/represent on a linear axis

IVOA May 2023 – P. Fernique

The idea (F.X.Pineau & B.Cecconi)

- Use **frequencies**
- Map values as a **logarithmic** expression, using the same principle as the coding of real numbers : mantissa and exponent
  - 52 bits for mantissa
  - 8 bits for exponent (not 11)
  - Save 4 bits for signature



IVOA May 2023 – P. Fernique 6

- The **original idea: 2023 Bologna** talk
  « *F-MOC: Towards a frequency MOC ?* » - Fernique & al.
- **No MOC standard evolution** yet since this date

The Frequency Discretisation magic formula

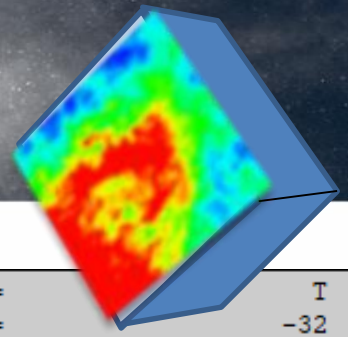
- Map values as a **logarithmic** expression, using the same principle as **the coding of real numbers** : mantissa and exponent
- **Very Fast** mapping
- Resulting **amplitude** (in Hz)
  - FREQ_MIN = **5.048709793414476e-29**
  - FREQ_MAX = **5.846006549323611e+48**
- **MAX_ORDER = 59**

```
long getHash(double freq) {
    long freq_bits = Double.doubleToLongBits(freq);
    long exponent = (freq_bits & F64_EXPONENT_BIT_MASK) >> 52;
    exponent = (exponent - 929) << 52;
    long hash = (freq_bits & F64_BUT_EXPONENT_BIT_MASK) | exponent;
    return hash;
}
```

```
double getFreq(long hash) {
    long exponent = (hash & F64_EXPONENT_BIT_MASK) >> 52;
    exponent = (exponent + 929) << 52;
    long freqBits = (hash & F64_BUT_EXPONENT_BIT_MASK) | exponent;
    double freq = Double.longBitsToDouble(freqBits);
    return freq;
}
```

This solution does the job
But…

Frequency HiPS3D impact



- HiPS3D is fully based on **FMOC**
- **HiPS3D tiles** have a spatial surface and a frequency thickness
- In FITS encoding: very useful to have **spatial-frequency WCS**

- Unfortunately, the **WCS standard hasn't covered the case** of bit shift expressions.

```
SIMPLE  =                    T
BITPIX  =                  -32
NAXIS   =                    3
NAXIS1  =                   15
NAXIS2  =                   14
NAXIS3  =                   16
COMMENT = 'HiPS FITS tile generated by Aladin/Hipsg
CRPIX1  =               -144368
CRPIX2  =                -60415
CD1_1   = -6.8664550781250E-04
CD1_2   = -6.8664550781250E-04
CD2_1   =  6.8664550781250E-04
CD2_2   = -6.8664550781250E-04
CTYPE1  = 'RA---HPX'
CTYPE2  = 'DEC--HPX'
CRVAL1  =                   0.
CRVAL2  =                   0.
PV2_1   =                    4
PV2_2   =                    3
CTYPE3  =
CUNIT3  =
CRPIX3  =
CRVAL3  =
CD1_3   =
CD2_3   =
CD3_1   =
CD3_2   =
CD3_3   =
```

?

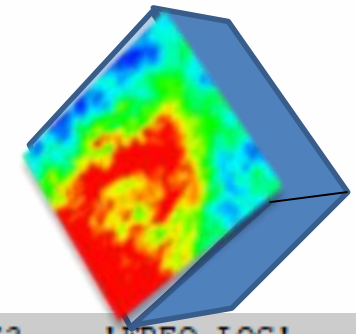
T.Robitaille summer proposal

```
def freq2index(freq):
  return log(freq) - log(FREQ_MIN))
      /  (log(FREQ_MAX) - log(FREQ_MIN)) * 2^ORDER))
```

```
def index2freq(index):
  return 10^(index / 2^ORDER * (log(FREQ_MAX)
      - log(FREQ_MIN)) +log(FREQ_MIN))
```

- A ‘simpler’ **logarithmic** expression
- **Still fast** mapping
- **Amplitude** (in Hz)
  - FREQ_MIN = 1e-18
  - FREQ_MAX = 1e+38
- **MAX_ORDER=51**

+ a **WCS solution**



```
CTYPE3  = 'FREQ-LOG'
CUNIT3  = 'Hz      '
CRPIX3  =                -813471
CRVAL3  =               1.0E-18
CD1_3   =                     0
CD2_3   =                     0
CD3_1   =                     0
CD3_2   =                     0
CD3_3   = 1.537141385169823E-23
```

WCS

CTYPE = ‘FREQ-LOG’
CUNIT = ‘Hz’
CRVAL = FREQ_MIN
CRPIX = 1-index*tileDepth
CD3_3 = CRVAL * log(FREQ_MAX / FREQ_MIN) / 2^ORDER

Summer discussion & Conlusion

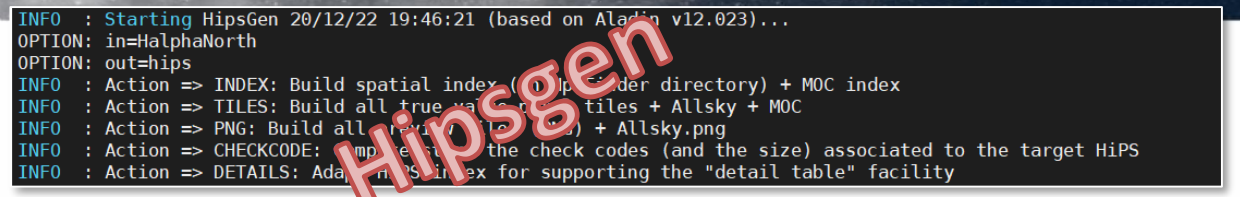
Tests comparing two spectral index encoding methods for HiPS3D show that ***the logarithmic approach is preferable to the mantissa–exponent method****. It simplifies* ***WCS handling in HiPS headers****, and its drawbacks (****slightly slower, fewer index levels, no bijectivity with doubles) have no practical impact****. It still exceeds current and future spectral resolution requirements, so the logarithmic method is recommended*

The new FMOC discretisation function

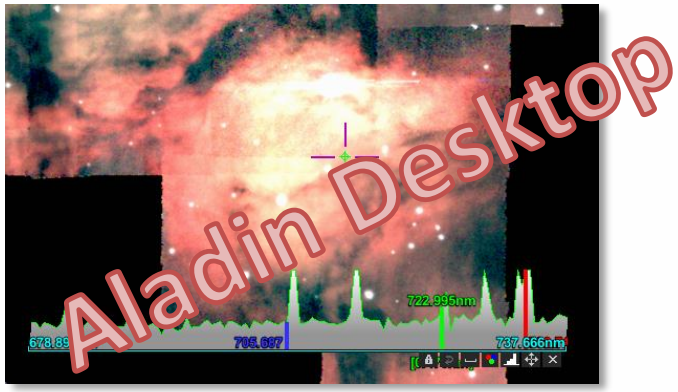
```
double FREQ_MIN = 1E-18;
double FREQ_MAX = 1E+38;
int    MAXORD_F = 51;
double CTE = Math.log10( FREQ_MAX/FREQ_MIN );
double POW2MAX = 1L << (MAXORD_F+1);

long getNpix(double freq) {
   return (long) ( ( Math.log10(freq/FREQ_MIN) / CTE ) * POW2MAX );
}

double getFreq( long npix ) {
   return FREQ_MIN * Math.pow( 10, CTE * npix / POW2MAX );
}
```

HiPS3D new tools collection updated after summer decision

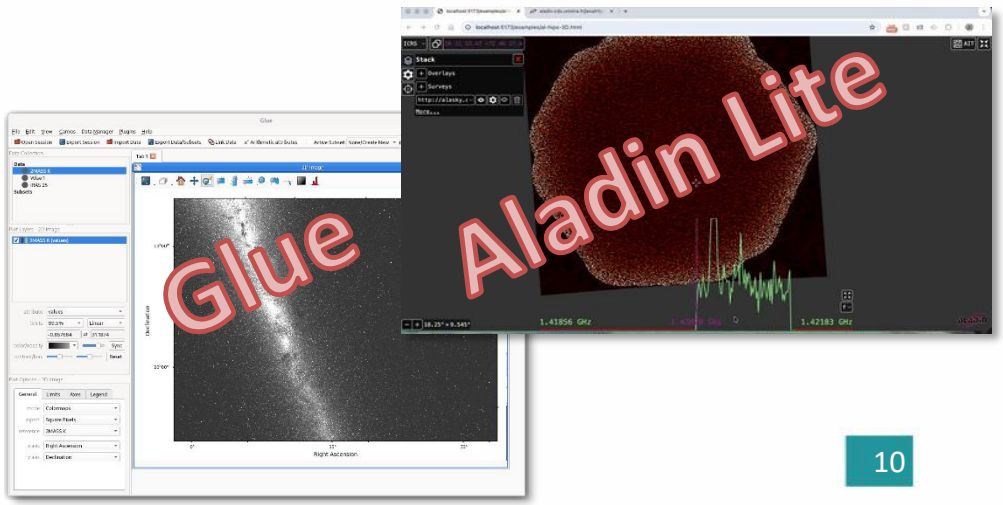
- **Hipsgen**: HiPS generation (public version)



- **Aladin Desktop:** Standalone HiPS visualization (version beta 12.6)
- **Aladin Lite:** Web HiPS visualisation (prototype v3.7)
- **Astropy/reproject/Glue**: Generation & visualisation [T.Robitaille]



- **Hips2fits3D** : Server side extraction of any cube at any resolution from a HiPS3D
  -> See T.Boch's ADASS poster

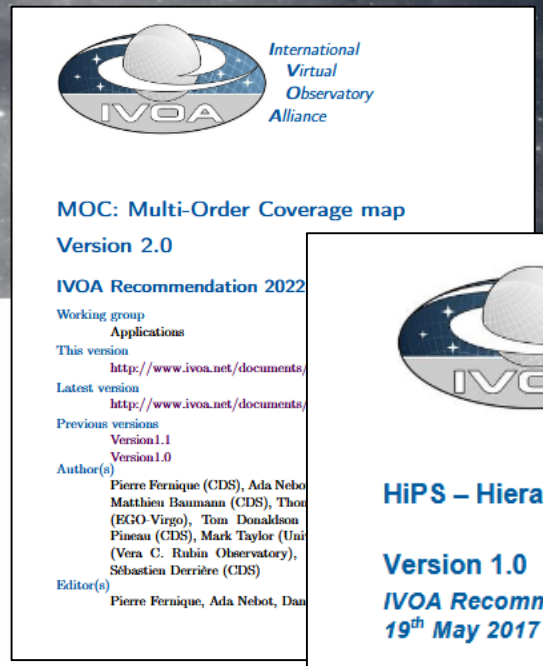


What about IVOA MOC & HiPS standard ?

- **HiPS & MOC are based on the same concepts**, which **must remain consistent**.

- **HiPS3D is progressing** very quickly:
  - Several interoperable implementations
  - Several surveys successfully tested
  - (Highly) interested missions and archives awaiting implementation: ALMA, SKA, etc.
  - Temporal HiPS3D very promising (see TDIG session)

- **Need to standardize** all of this within the IVOA framework:
  - MOC2.0 -> **MOC3.0 incorporating FMOC** (new formula)
    - Volunteer editor: François-Xavier Pineau et al.
  - HIPS1.0 -> **HIPS2.0 incorporating HIPS3D** (frequency and time)
    - Volunteer editor: Pierre Fernique et al.


International Virtual Observatory Alliance

MOC: Multi-Order Coverage map

Version 2.0

IVOA Recommendation 2022

Working group
Applications

This version
http://www.ivoa.net/documents/

Latest version
http://www.ivoa.net/documents/

Previous versions
Version1.1
Version1.0

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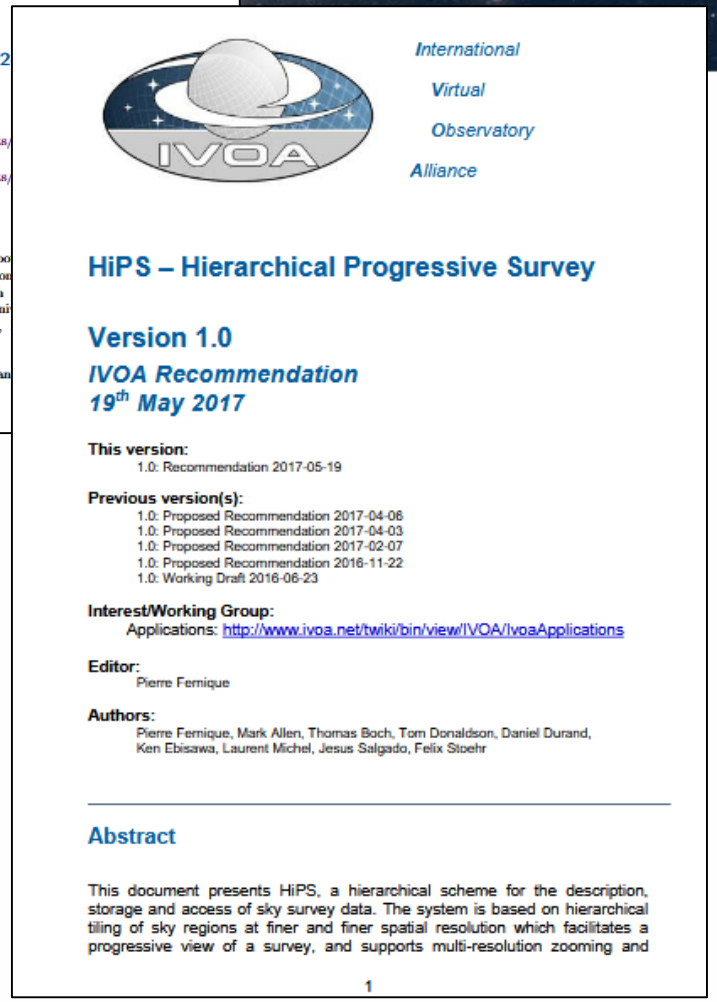
International Virtual Observatory Alliance

HiPS – Hierarchical Progressive Survey

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/twiki/bin/view/IVOA/IvoaApplications

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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

1

Do Apps' members agree?

Thanks !
Questions ? Comments ?