Innovative Tools Fostered by the HiPS Ecosystem

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Abstract.

Over the past 10 years HiPS (Hierarchical Progressive Surveys) has evolved from an experiment led by CDS to an ecosystem supported by more than 20 data centers exposing their own HiPS node. This trend has been pushed by advanced and simple clients (Aladin Desktop, Aladin Lite) or portals (ESASky, ESO Science Portal) and thanks to Hipsgen. Today the HiPS ecosystem gathers 900 HiPS datasets published by 20+ HiPS nodes. We describe a selection of different tools and services that benefit from having a large collection of multi-wavelength datasets available in the same format: hips2fits, on-the-fly generation of RGB tiles from pre-existing HiPS, HiPS as a container for 1d and 2d histograms, CatTiler, computation on the HiPS grid, generation of Spectral Energy Distribution from FITS tiles.

1. HiPS - A generic data container

The Hierarchical Progressive Survey (Fernique et al. 2015) scheme based on HEALPix (Górski et al. 2005), and standardised by IVOA[1] (Fernique et al. 2017) has evolved into a ecosystem which includes a network of data centres who make their HiPS nodes available, and easily implementable applications, principally Aladin Lite (Boch & Fernique 2014) for their use. HiPS can be considered as a generic container for different types of data such as images and catalogues, and more generally any type of data that can be associated with a position on the sky (e.g. density maps, time series, spectra, etc.). The concept as a container, and also other capabilities for obtaining data, in particular the IVOA Table Access Protocol (TAP, Dowler et al. (2019)) can be combined in ways that enables many new and innovative ways of using all-sky data. In this paper we describe some of these new capabilities.

As a first illustration, consider all of the catalogues that have been published in the CDS VizieR service from the A&A journal over the 50 year lifetime of the journal. The VizieR TAP (Landais et al. 2013) service allows all 7533 of these catalogues to be queried with ADQL in a way that creates a density map of all of the catalogue

[1] https://ivoa.net/documents/HiPS/

sources, gridded onto to a HEALPix grid of a chosen resolution. And indeed a full multi-resolution HiPS of these data may be constructed. Figure 1 shows the resulting density map.

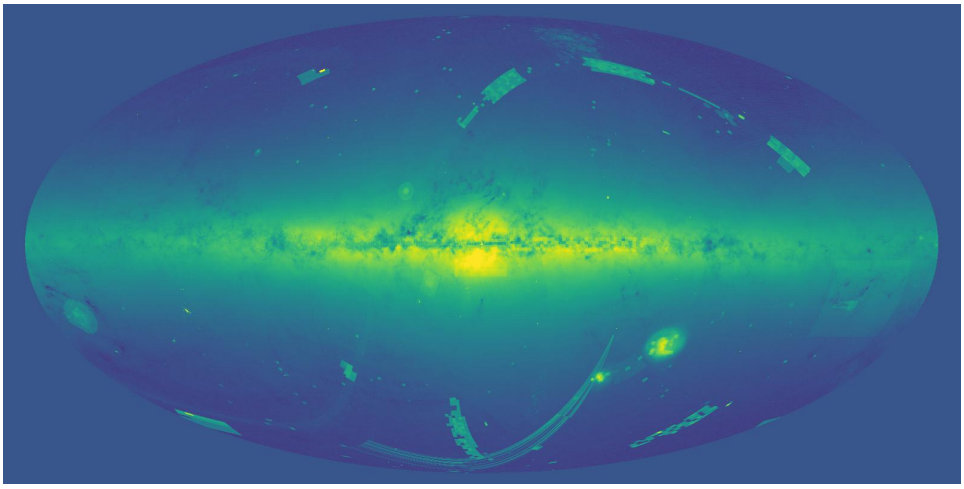

Figure 1. All-sky density map of catalogues from all A&A papers up to 2020

We have also used the HiPS structure to store 2D histograms (each HiPS tile containing the histogram values for that part of the sky), as to allow for dynamic generation of color-magnitude diagrams for the displayed view, as shown in Figure 2.

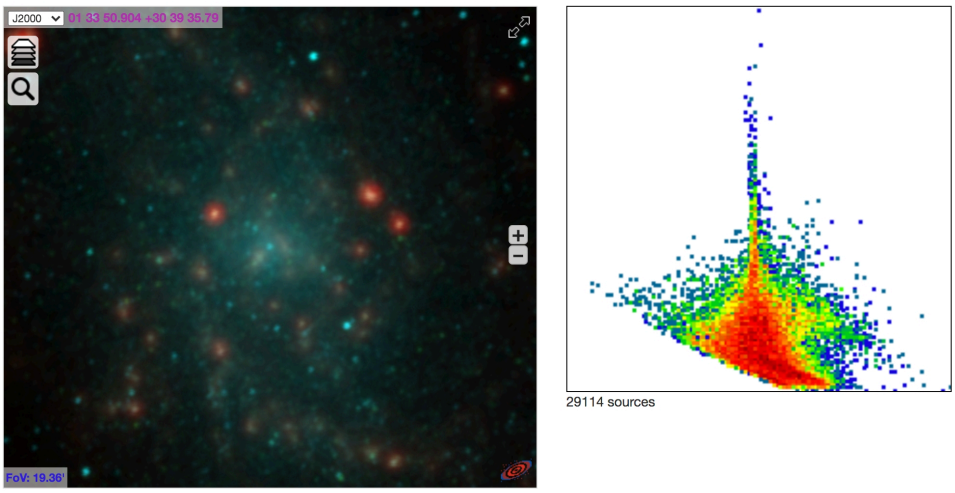

Figure 2. Colour-Magnitude diagram generated from HiPS

2. Computation on the HiPS grid and on-the-fly color HiPS generation

As the HiPS datasets in the same coordinates system utilise the same HEALPix grid, it is straightforward to make some computations that combine different HiPS datasets, at any scale. This can be used for instance to provide moment-0, moment-1 and moment-2 of HiPS data cubes. The common grid also facilitates the mixing of tiles from different HiPS datasets in order to create a new colour HiPS, allowing easy colour combination and multi-wavelength comparison.

3. CatTiler

CatTiler is a prototype service aimed at interactive exploration of large catalogues. Data are aggregated by a TAP server, and are then transformed to a HiPS tile, as illustrated in the Figure 3.

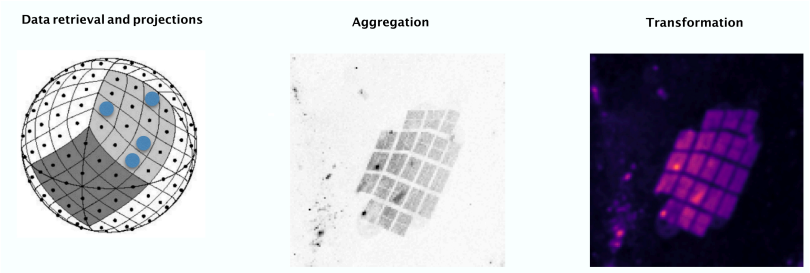

Figure 3. Schematic flow of CatTiler

CatTiler takes advantage of the HEALPix User Defined Function *ivo_healpix_index* available in some TAP services to generate HiPS density tiles from ADQL queries, possibly weighted by a given column and with additional constraints. Figure 4 shows a typical ADQL query used to generate a HiPS density tile for 2MASS sources.

```
SELECT ivo_healpix_index(10, ra, dec) AS ipix, COUNT(*) AS cnt
    FROM "II/246/out"
    WHERE ivo_healpix_index(3, ra, dec)=528
      AND Kmag-Jmag>1
    GROUP BY ipix
```

Figure 4. Example of ADQL query submitted to TAP VizieR by CatTiler

4. hips2fits

The *hips2fits* service generates arbitrary FITS cutouts from HiPS FITS tiles, for any public HiPS dataset. As HiPS data have been generated at different orders, we obtain a constant computation time of 500k pixels/second, regardless of the requested resolution. These cutouts can be easily created from the *astroquery.cds* package. The hips2fits code has already been used to generate millions of training data cutouts for machine learning purposes.

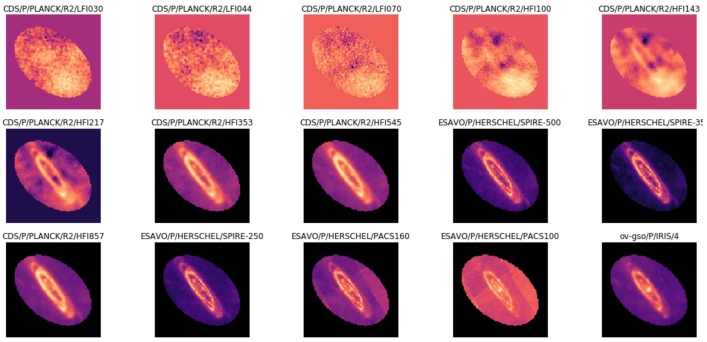

Figure 5. Cut-out images from 15 different HiPS for Messier 31 generated by *hips2fits*

5. SED from HiPS FITS tiles

We developed an early-stage prototype to extract a Spectral Energy Distribution for an arbitrary region, from FITS tiles. The first results are promising and pinpoint the need for an accurate characterization and description of the flux unit in the HiPS metadata.

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