

gamma-sky.net: Portal to the Gamma-Ray Sky

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Abstract. gamma-sky.net is a novel interactive website designed for exploring the gamma-ray sky, targeting both practitioners of astronomy and the general public alike. Our poster displays the content of our online portal, featuring high-energy survey images and catalog information using data from the Fermi Large Area Telescope (Fermi-LAT). Users can interact with the archive through a pan-and-zoom feature and powerful search tools. As the field of gamma-ray astronomy develops, we plan on expanding the website with more publicly available gamma-ray data, including High Energy Spectroscopic System (H.E.S.S.) Galactic Plane Survey maps (upon their public release) and survey images from the Planck satellite. Along with enriching our database, we also aim to make available to the user additional engaging and resourceful tools, such as a display of spectral information. The website is being developed as an open-source, open-data project at <https://github.com/gammapy/gamma-sky>. Feedback and contributions are very welcome!

TODO: update abstract after main article is written!

References

References that have been mentioned (list ordered by which was mentioned first):

- HGPS
- HiPS
- 3FGL
- 2FHL
- SNRcat
- Gammapy
- Aladin Lite

TODO: Should we mention TeVCat or TGeVCat, and where?

TODO: See TODO in Introduction section for more missing citations.

Introduction

The field of very-high-energy (VHE) astronomy is growing tremendously – while only a decade ago we observed no more than a handful of sources in the GeV range, today we have thousands, including hundreds within the TeV range. This advancement has been made possible due to our novel ground-based Cherenkov telescope instruments. Such systems exhibit more accurate source detections higher angular resolutions than ever before. Space-based satellites sharing similar technological breakthroughs have further developed the high-energy (HE) range of gamma-ray astronomy, as can be observed in the latest images from the Fermi Large Area Telescope (Fermi-LAT). As a whole, the instruments can capture gamma-rays in a wide spectrum of energies from 10 MeV to 10 TeV. The High Energy Stereoscopic System (H.E.S.S.) Galactic Plane Survey [1], the High-Altitude Water Cherenkov Observatory (HAWC) 1st Year Catalog, and the fourth Fermi-LAT Point Source Catalog (4FGL) are among the highly anticipated surveys that will be unveiled in the near future. Furthermore, with an incoming wave of notable systems planned to operate soon, such as the ground-based Cherenkov Telescope Array (CTA), we expect to discover numerous never-before-seen sources in the gamma-ray sky. With such abundance of HE and VHE sources and a rapid growth of interest in

gamma-ray astronomy, there is an evident need for a central hub of all relevant catalog and image data. Our website (<http://gamma-sky.net>) was designed to function as such.

TODO: Add citations for: HAWC first year catalog, 4FGL, CTA? Or should we remove these references? Maybe for some we can reference just websites like TeVCat did in their paper?

Idea

gamma-sky.net is a one-stop resource for browsing images and catalogs but also for closely examining a specific gamma-ray source. Although it was mainly built for the greater astronomical community, the webpage additionally targets the general public through a user-friendly interface and a clean information layout, all of which are compiled under cutting-edge web tools.

Individuals who access the website via any modern internet browser will be welcomed with the Map View page. This page presents an overlay of multi-wavelength survey images, most of which are all-sky images, wrapped around a three-dimensional sphere. The map features pan-and-zoom functionality for easily navigating and quickly browsing the sky. Gamma-ray sources from our catalog data have been pinpointed onto the sphere, as shown in Figure 1. The Map View page also utilizes a powerful search tool to either pan the view to a given sky position or locate a source by name. This functionality allows the user to easily find their sources and study their visual context in relation to other objects. gamma-sky.net additionally embodies a Catalog View, which incorporates more detailed information for each of the sources in our catalogs. Professional astronomers will navigate to this component of the website for the deep investigation of a particular source. See the Catalog View page in Figure 2.

It is imperative for all of our data on the online portal to be openly available for download and local analysis by any user. Additionally, gamma-sky.net is an entirely open-source project and other developers are welcome to contribute to the code. We advise those interested in contributing to visit our GitHub repository at <https://github.com/gammipy/gamma-sky>.

Features

The items listed below illustrate the interface of gamma-sky.net and its utilization as a tool for astronomers.

1. **Browsing and navigation features** in the Map View component:

- Pan and zoom
- Search tools - locate objects by name, association, or coordinate position
- Toggle and view specific catalog layers and sky images
- Pop-up information over each source
- Export and share images from the sky map (in PNG format)

2. **Analysis tools** in the Catalog View component*:

- Search and select a source by its name
- Basic information - position, association and class
- Extension information
- Spectral index, brightness and flux
- Distance and redshift
- Graphs of light curves and emission spectra
- Detection/observation information - instrument, date of discovery and relevant papers

TODO: How does this features list look? Should we make it more “elegant”/space them out a bit?

Data

The default base image layer displayed on gamma-sky.net’s Map View page is a multi-wavelength all-sky survey from Fermi-LAT. In its native color map, source regions appear as certain colors according to their determined energies -

*Some of the features listed for the Catalog View are currently only available for select catalogs, but they are expected to be a part of all catalogs in the near future.

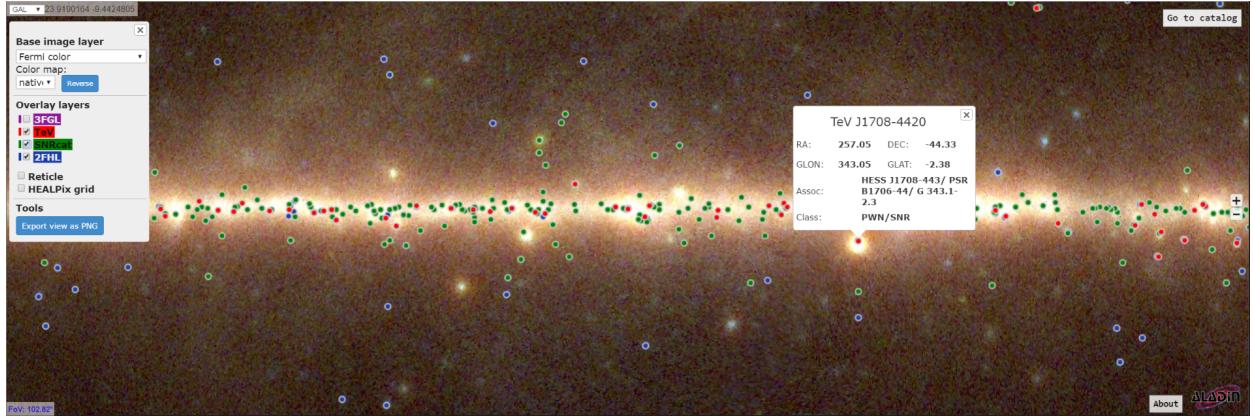


FIGURE 1. Map View.

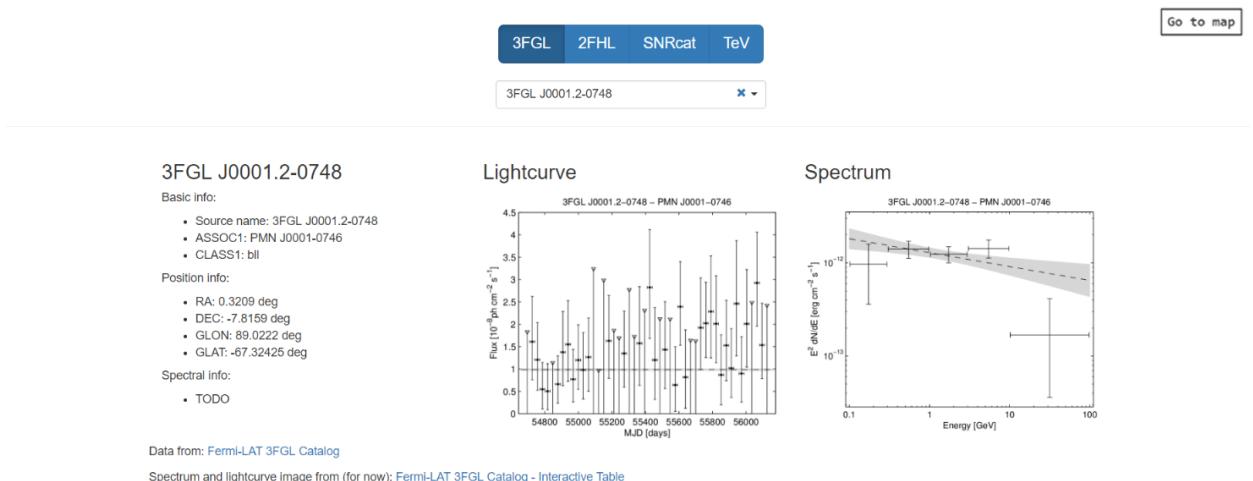


FIGURE 2. Catalog View.

red/yellow for 300-1000 MeV, green for 1-3 GeV, and blue for 3-300 GeV. The Fermi color image is presented on the website as a Heirarchical Progressive Survey (HiPS) image [2]. HiPS is a heirarchical data structure utilizing the HEALPix¹ tessellation of a sphere that organizes data onto pixelated tiles of scalable resolution. The image mechanism allows catalog data and source markers on gamma-sky.net to be visualized accurately on the sky map at various zoom levels. The Centre de Données astronomiques de Strasbourg (CDS) developed the HiPS technology, and gamma-sky.net currently encompasses 8 survey images also prepared by CDS in this format. The 8 images, which are outlined in Table 1, come from CDS's HiPS database², of over 300 prepared HiPS images.

Our website incorporates 4 catalogs which are displayed in Table 2. 3FGL [3] and 2FHL [4] are the latest surveys from Fermi-LAT, the main space-based instrument we display sources from. SNRcat [5] is an up-to-date compilation of galactic SNRs observed from a variety of instruments. The database is maintained by the University of Manitoba and can be accessed at <http://www.physics.umanitoba.ca/snr/SNRcat/>. gamma-cat is an open-data catalog of sources in the TeV range. As a project that has just recently begun in early September 2016, it is undergrowing rapid growth and will be updated frequently on gamma-sky.net. gamma-cat was started at the Max-Planck-Institut für Kernphysik (MPIK) and is open to contribution from other developers. All of its catalog information can be found at <https://gammapy.github.io/gamma-cat/>.

¹<http://healpix.sourceforge.net/>

²<http://aladin.u-strasbg.fr/hips/list>

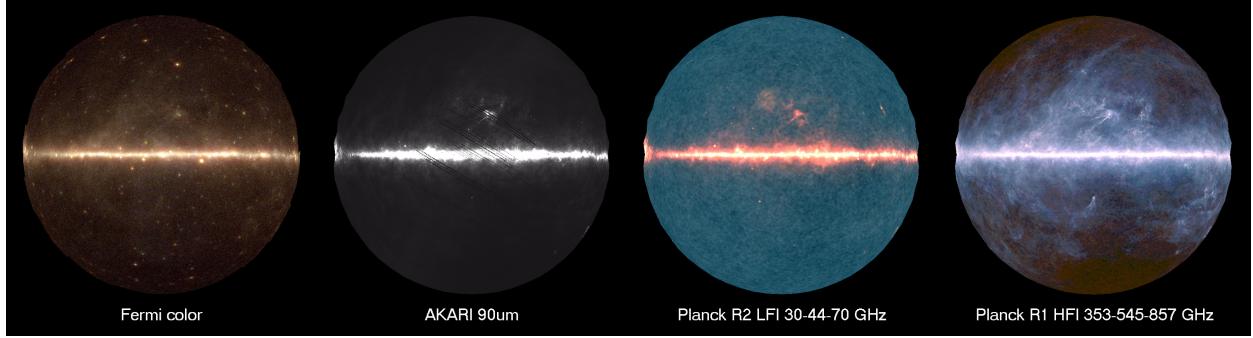


FIGURE 3. Survey images (left to right): Fermi color, AKARI 90um, Planck LFI, Planck HFI. Images centered on the Galactic Center, FOV 180 degrees.

TABLE 1. Image information.

Image	Resolution (arcmin)	Type	Band	Coverage
AKARI 90um	1	infrared		all-sky
CGPS-VGPS CONT	1	radio		galactic plane
Fermi-LAT	TBD	gamma-ray		all-sky
Haslam 408	51	radio	408 MHz	all-sky
IRIS Band 4-100um	TBD	infrared		all-sky
Planck R1 + R2 HFI	TBD	microwave	353-545-857 GHz	all-sky
Planck R2 LFI	TBD	microwave	30-44-70 GHz	all-sky
Spitzer GLIMPSE360	0.02	infrared		galactic plane

User inputs for search fields under the Map View portion of the website are interpreted by the Sesame service³. Sesame is a search term resolver for astronomical objects which queries several databases and returns the resolved sources. Both Sesame and the databases searched (Simbad, NED, and VizieR) are maintained by CDS.

Under the Catalog View of gamma-sky.net, we are currently showing 3FGL light curve and emission spectrum plots from NASA's Fermi-LAT 3FGL Catalog Interactive Table⁴.

TODO: Fix table + image placement after all other text is finalized.

TODO: For the image table (Table 2), we need to fill in the rest of the Band column (or remove the column altogether)

Implementation

Scientific Python packages Astropy and Gammmapy [6] were used to prepare and generate all of the catalog and source data on gamma-sky.net. The data is consumed with the JavaScript and HTML frontend. The website's architecture was organized using Angular 2, a modern web application framework for JavaScript. Using Angular 2 has allowed

TABLE 2. Catalog information.

Catalog	Sources	Period	Description
gamma-cat	153	continuous	Open TeV gamma-ray source catalog
2FHL	360	2 years	Second Fermi-LAT catalog of high-energy sources
3FGL	3034	4 years	Third Fermi-LAT point source catalog
SNRcat	378	continuous	A census of high-energy observations of Galactic supernova remnants

³<http://cds.u-strasbg.fr/cgi-bin/Sesame>

⁴http://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/3FGL-table

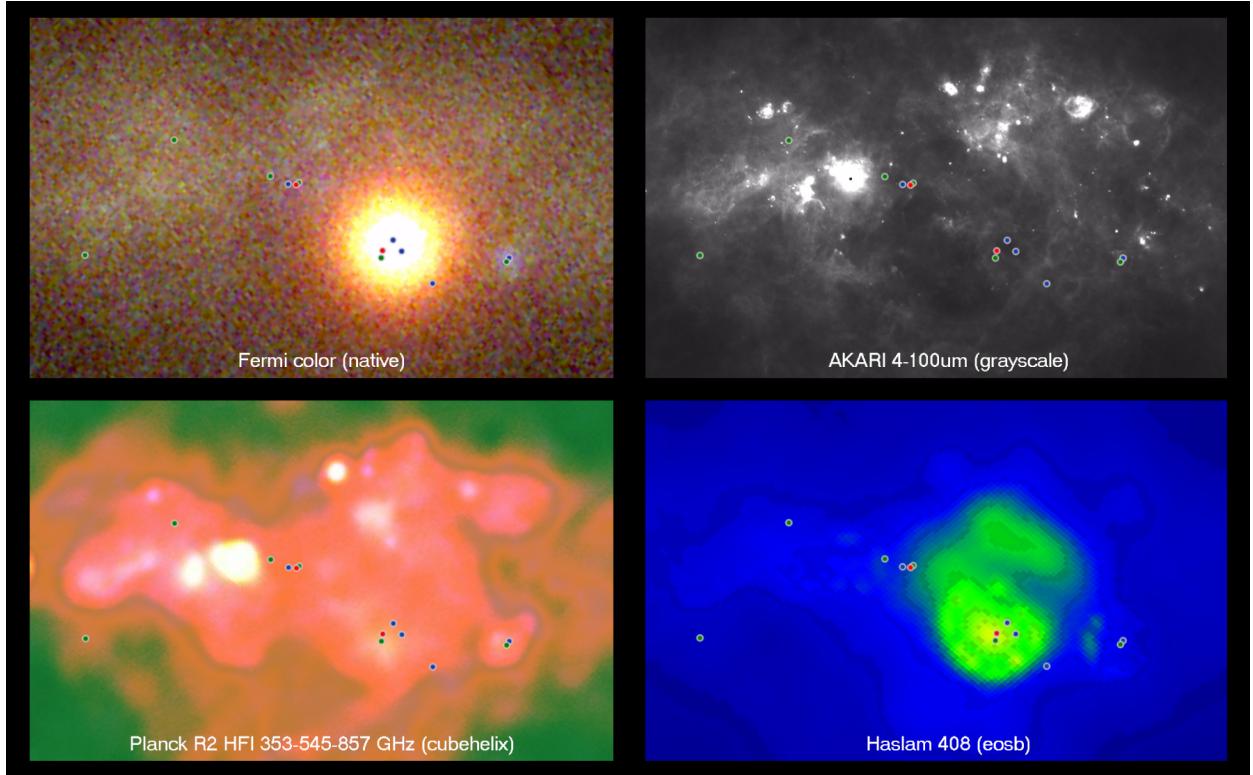


FIGURE 4. The Vela Region in various survey images and color maps, FOV 20 degrees.

us to compile gamma-sky.net into a single-page application. The sphere interface and visualization was implemented using the Aladin Lite tool [7] developed at CDS.

TODO: Explain/mention Gammappy in more detail?

Status and Outlook

Our website is a new project, having been deployed very recently at <http://gamma-sky.net> in early June 2016. The website is being hosted by GitHub Pages. The current content of our website is merely a starting point; we have plans to greatly expand on our catalog and image data. Such data includes additional surveys from CDS' HiPS database, as well as source and image data from upcoming surveys upon their public release. We additionally strive to enhance the user interface of gamma-sky.net through additional features - including new source groupings by classification and position, deeper communication between the Map View and Catalog View, and more intricate data panels for the Catalog View.

Acknowledgements

We would like to thank the CDS (Centre de Données astronomiques de Strasbourg) for developing the data formats (HiPS) and tools (Aladin Lite) that make gamma-sky.net possible. Thomas Boch helped us to understand Aladin Lite and apply it to our use case.

We would also like to thank Github for hosting the gamma-sky.net website, and CDS for serving the HiPS images, as well as the people that have contributed to the open-source projects we use to build gamma-sky.net: the angular web framework as well as the Astropy and Gammappy Python packages.

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