

# 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

TODO: References that should be mentioned somewhere in the proceeding:

- [1] – TeVCat: An online catalog for Very High Energy Gamma-Ray Astronomy (<http://tevcat.uchicago.edu/>)
- [2] – The Very High Energy source catalog at the ASI Science Data Center (<http://www.asdc.asi.it/tgevcat/>)
- [3] – Fermi Large Area Telescope Third Source Catalog
- [4] – 2FHL: The Second Catalog of Hard Fermi-LAT Sources
- [5] – A census of high-energy observations of Galactic supernova remnants (<http://www.physics.umanitoba.ca/snr/SNRcat/>)
- [6] – Hierarchical progressive surveys (HIPS) (<http://aladin.u-strasbg.fr/hips/>)
- [7] – Aladin Lite: Embed your Sky in the Browser (<http://aladin.u-strasbg.fr/AladinLite/>)
- [8] – Gammapy - A Python package for gamma-ray astronomy (<http://gammapy.org/>)
- 3FGL interactive table - ([http://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr\\_catalog/3FGL-table/](http://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/3FGL-table/))
- [9] – H.E.S.S. Galactic plane survey (HGPS) – upcoming TeV maps and catalog we will add.

## Introduction

- Evolution of VHE gamma-ray astronomy - increasing number of detections, novel Cherenkov telescope arrays (especially CTA)
- Upcoming surveys like HGPS (by MPIK) - clearer resolution than our current surveys
- Because of an increasing interest in the field, there is a need for a hub of VHE data (GeV, TeV) across many different catalogs. This is what gamma-sky.net was created for.

The field of very-high-energy (VHE) astronomy is growing tremendously – while only a decade ago we 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 have a higher angular resolution than ever before. Space-based satellites for missions in high-energy (HE) astronomy also share similar advancements, as can be observed in the latest images from the Fermi Large Area Telescope (Fermi-LAT). As a whole, these instruments can capture gamma-rays in a wide spectrum of energies from 10 MeV to 10 TeV. Many notable instruments are expected to unveil new surveys in the near future. Such surveys include the High Energy Stereoscopic System (H.E.S.S.) Galactic Plane Survey and the High-Altitude Water Cherenkov Observatory (HAWC) 1st Year Catalog. Furthermore, with an incoming wave of systems planned to operate soon, such as the ground-based Cherenkov Telescope Array (CTA), we will expect to discover numerous never-before-seen sources in the gamma-ray sky. With such abundance of VHE sources and rapid growth of interest in gamma-ray astronomy, there is an evident need for a central hub for all relevant catalog and image data. Our website (<http://gamma-sky.net>) was designed to function as such.

## Idea

- Interactive website designed for exploring the gamma-ray sky
- Survey images of different frequency bands (mainly all-sky) overlaid onto a three-dimensional map. Gamma-ray sources from catalog data are pinpointed onto the map.
- The website facilitates both quick browsing and deep investigation of sources
- Understand the context of sources by viewing them on the map
- Easily compare sources from different catalogs
- Website targets professional astronomers, but also the general public through a user-friendly interface and the easily understandable layout of sources plotted over a map.
- Open source, open data - allows for 1. users to download any data from our website, and 2. for other developers to contribute to the code.

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

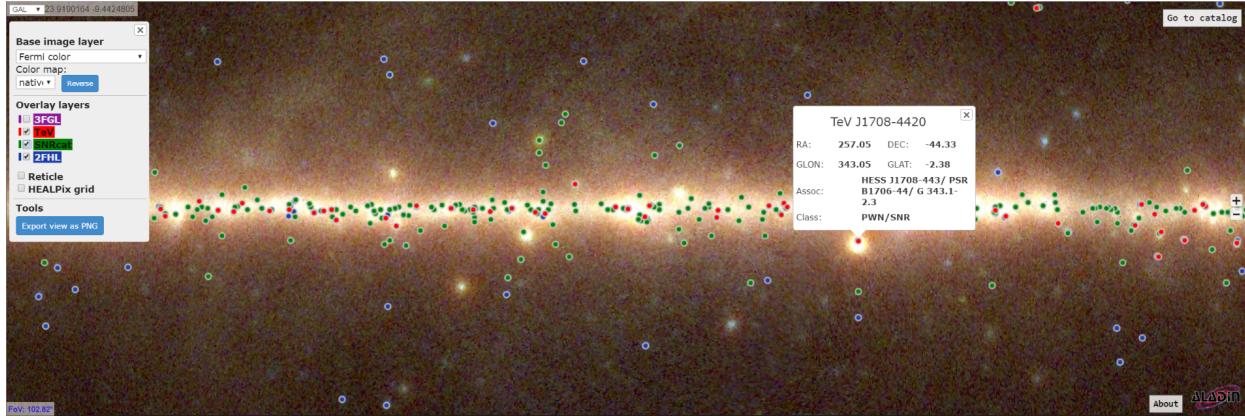
Individuals who access the website via any modern internet browser will be welcomed with the Map View page. This page presents an overlay of multi-wavelength survey images, most of which are all-sky images, wrapped around a three-dimensional sphere. The map features pan-and-zoom functionality for easily 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 also utilizes a powerful search tool to either pan the view to a given sky position or locate a specific source by name. These features allow 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 Figure 2 for the catalog view.

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 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>.

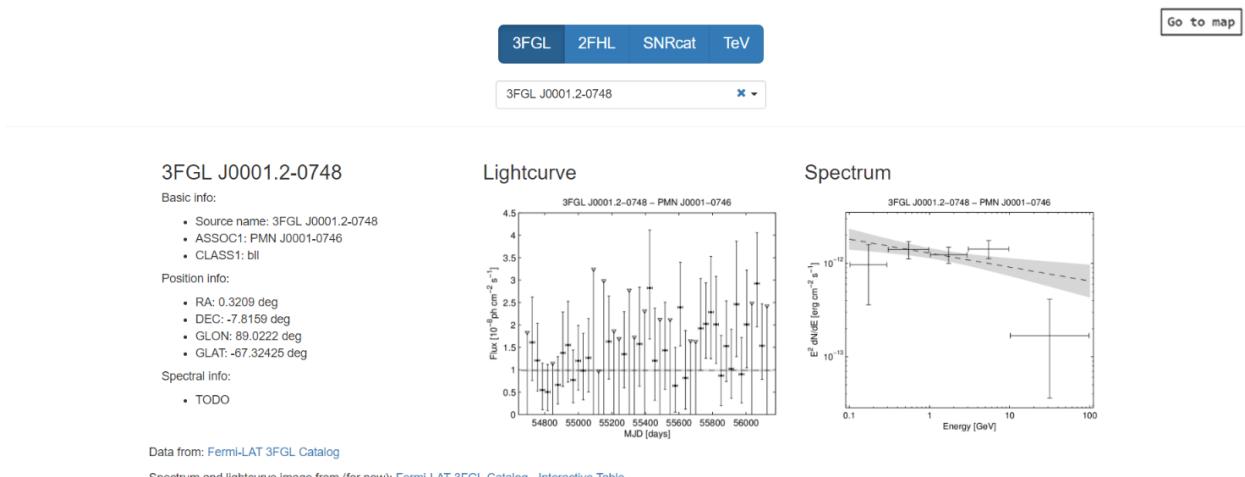
## Features

(Should we present this information in a bullet list or in paragraphs?)

1. Map View - easy navigation and quick browsing
  - Pan and zoom the sky map by dragging and scrolling
  - Toggle and view specific catalog layers and multi-wavelength survey images
  - Pop-ups over each source for basic information
  - Powerful search tools - locate objects by name, association, or coordinate position



**FIGURE 1.** Map View.

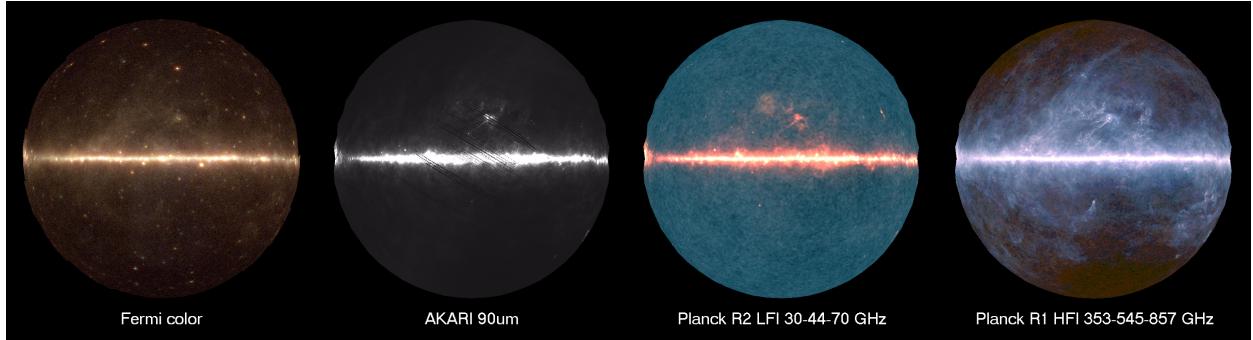


**FIGURE 2.** Catalog View.

- Export and share a specific view of the sky map via PNG
2. Catalog View - deeply investigate a specific source
    - Search tool to find a source in its respective catalog by source name
    - Basic info, extension info, spectral info, distance info
    - Light curves, emission spectra (currently only for 3FGL catalog)
    - References to which telescope detected the source and links to where our data came from
  3. Further analysis of our data with tools like Gammmapy (generate specific plots, etc.)
  4. Mention again that all data is openly available for download

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

1. **Browsing and navigation features** as a part of the Map View component of the website:
  - Pan and zoom
  - Search tools - locate objects by name, association, or coordinate position. These user inputs are interpreted by the Sesame service, 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 the Centre de Données astronomiques de Strasbourg (CDS).



**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.** Catalog information.

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

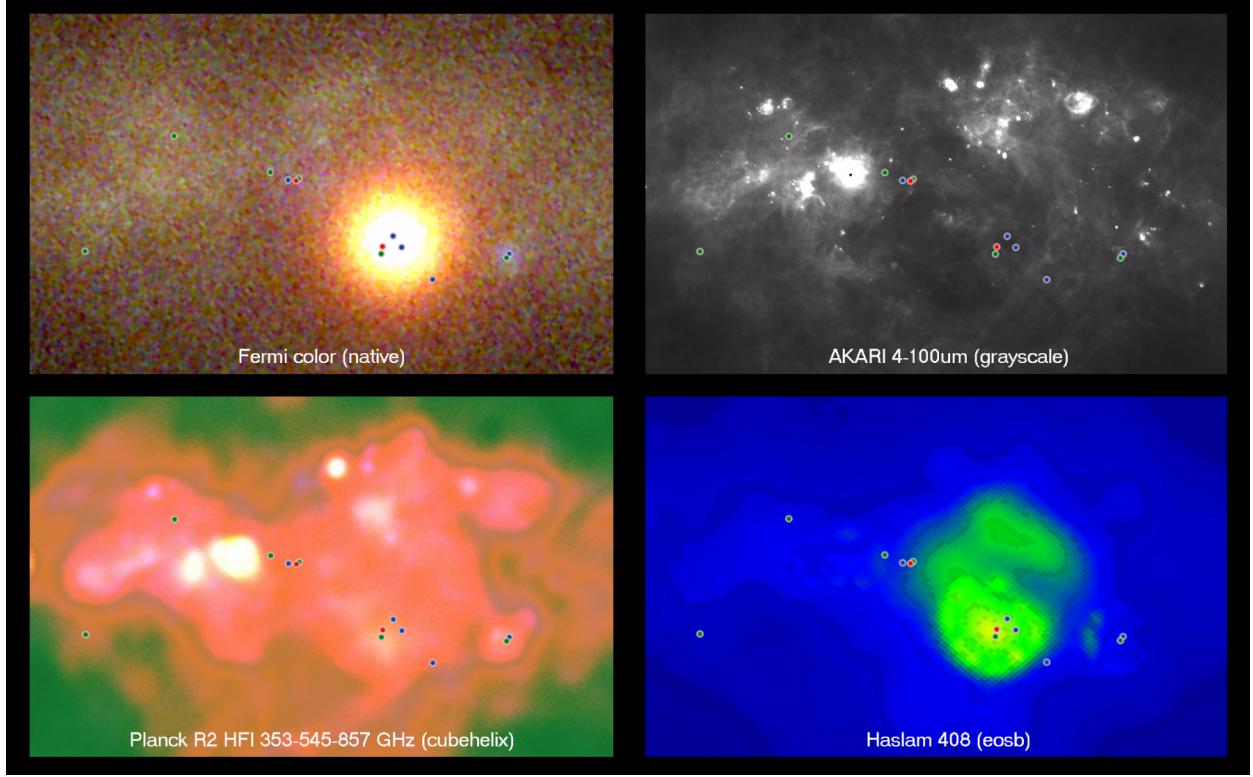
- Toggle and view specific catalog layers and sky images
  - Pop-up information over each source
  - Export and share images from the sky map (in PNG format)
2. **Analysis tools** under gamma-sky.net's Catalog View\*:
- Search and select a source by its name
  - Basic information - position, association 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

## Data

1. Survey images
  - Default: Fermi color image. Mention other survey options
  - HiPS file format and HEALPix projection for the map
  - Our images came from CDS' HiPS database of 300+ images
2. Catalogs
  - Fermi-LAT - 3FGL and 2FHL
  - SNRcat
  - gamma-cat open TeV source catalog

The default survey image displayed on gamma-sky.net's Map View page is a multi-wavelength all-sky survey from Fermi-LAT. In its native color map, sources are assigned certain colors according to their determined energies - red/yellow at 300-1000 MeV; green at 1-3 GeV; and blue at 3-300 GeV. The Fermi color image was distributed by NASA's SkyView Virtual Observatory and is stored as a "Hierarchical Progressive Survey" (HiPS) image. HiPS is

\*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.



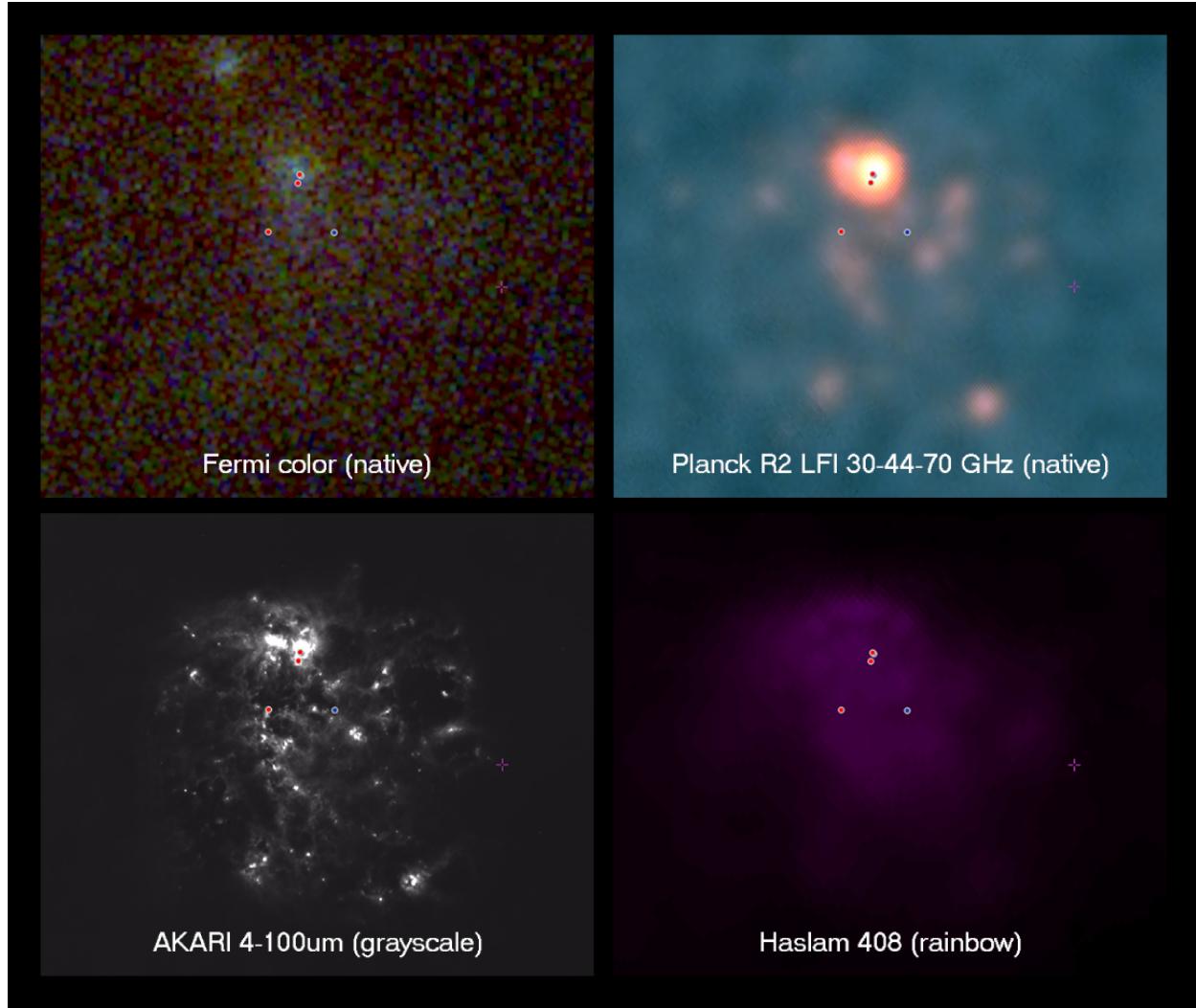
**FIGURE 4.** The Vela Region in various survey images and color maps, FOV 20 degrees.

a heirarchical data structure utilizing the HEALPix tessellation of a sphere that organizes data onto pixelated tiles of scalable resolution. The HiPS image mechanism allows catalog data on gamma-sky.net to be visualized accurately on the sky map at various zoom levels. HiPS was developed under the Centre de Données astronomiques de Strasbourg (CDS). gamma-sky.net currently encompasses 8 survey images prepared in HiPS format, as illustrated in Table 2. All of the images come from the CDS's HiPS database, containing a total of over 300 HiPS images.

Our website incorporates 4 catalogs, which are displayed in Table 1. 3FGL and 2FHL are the latest surveys from Fermi-LAT, which is the main space-based instrument we display sources from. SNRcat 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), but is open to contribution from other developers. All of the catalog information can be found at

**TABLE 2.** 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



**FIGURE 5.** The Large Magellanic Cloud (LMC) in various survey images and color maps, FOV 10 degrees.

<https://gammify.github.io/gamma-cat/>.

User inputs for search fields under the Map View portion of the website are interpreted by the Sesame service. 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 borrowing 3FGL light curve and emission spectrum plots from NASA's Fermi-LAT 3FGL Interactive Table, which can be accessed at [http://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr\\_catalog/3FGL-table](http://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/3FGL-table).

## Implementation

- Gammapy, Astropy used to generate catalog data (and map data)
- Data consumed with JS and HTML
- Website architecture built with Angular 2 as a single-page app
- Sphere interface and maps overlay by Aladin Lite tool

## Status and Outlook

- Website published in early June 2016
- Mini-summary of the website's current state
- Future plans for data - add HGPS, HAWC survey, upcoming Fermi catalogs, etc.
- Future plans for features

## Acknowledgements

- CDS
- SNRcat
- GeTeV Catalogue
- Dan's 3FGL interactive table
- GitHub Pages?

## REFERENCES

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