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# The Very High Energy source catalog at the ASI Science Data Center

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## ABSTRACT

The increasing number of Very High Energy (VHE) sources discovered by the current generation of Cherenkov telescopes made particularly relevant the creation of a dedicated source catalogs as well as the cross-correlation of VHE and lower energy bands data in a multi-wavelength framework. The “TeGeV Catalog” hosted at the ASI Science Data Center (ASDC) is a catalog of VHE sources detected by ground-based Cherenkov detectors. The TeGeVcat collects all the relevant information publicly available about the observed GeV/TeV sources. The catalog contains also information about public light curves while the available spectral data are included in the ASDC SED Builder tool directly accessible from the TeGeV catalogue web page. In this contribution we will report a comprehensive description of the catalog and the related tools.

**Keywords:** Very High Energy Astrophysics, Imaging Atmospheric Cherenkov Telescopes, Data Center, Source Catalog

## 1. INTRODUCTION

The current wealth of available astronomical data makes particularly important the appropriate handling of such an amount of information in order to achieve the maximum scientific output. Cross correlation and multi-band analysis between data coming from different energy ranges are going to play a key role in modern astrophysics due to the simultaneous availability of new generation space-based and ground-based observatories. An improving multi-wavelength analysis capabilities will be of crucial importance in the VHE band where a new golden-age is approaching thanks to the forthcoming construction of the *Cherenkov Telescope Array* (CTA).<sup>1</sup> The CTA, a worldwide initiative to build the next generation ground-based VHE gamma-ray instrument will deeply explore our Universe in the VHE gamma-rays and will investigate cosmic non-thermal processes, in close cooperation with both space- and ground-based observatories operating at lower energies of the electromagnetic spectrum, and those using other messengers such as cosmic rays and neutrinos. CTA will increase the sensitivity by a factor  $\sim 10$  compared to current VHE instruments, and it will enlarge the energy domain from a few tens of GeV to hundred of TeV with unprecedented angular and energy resolution leading to the discovery of more than 1000 ew sources. CTA will serve as an open observatory to a wide astrophysics community and this make particularly relevant the appropriate data handling and data cross matching with other bands.

The ASI Science Data Center is involved in the CTA activities in close collaboration with Italian National Institute of Astrophysics (INAF). ASDC is participating to the activities regarding data handling, data processing, data management and data access. In particular, ASDC will be able to adapt its web tools, at the moment used to access data by all the ASDC supported missions, to access also CTA data. ASDC web tools will allow to easy obtain and collect multi-wavelength information on CTA sources. In this context, a new VHE source catalog has been prepared in ASDC and it is available on-line: TeGeV catalog (<http://www.asdc.asi.it/tgevcat/>). The TeGeVcat is collecting all the information publicly available on the TeV sources observed by Cherenkov detectors including light curves and spectral points.

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## 1.1 The ASI Science Data Center

The ASDC (see Ref. 2 and 3) is the direct evolution of the first science data center of ASI created to host data of the Italian-Dutch X-ray mission BeppoSaX in late 1990s. Basing on that experience, ASDC has been developed as a facility able to provide high level services and products for data access and analysis to a large scientific community. The ASDC system has been designed to support the activities of several missions. Its strongest peculiarity lies in the cross-correlation of data coming from different archives at different energies. To this purpose, several tools were developed and are currently available on a web-based interface. The ASDC archive system provide non-simultaneous access to data coming from different (mainly space-based) observatories through an homogeneous HTML interface that constitutes a Multi-Mission Interactive Archive (MMIA). The overall system is driven by a DBMS that involve, depending on the specific mission requirements, the original Browse system or a MySQL relational database. Fast Visualization of the MMIA data is provided by a dedicated Multi-Frequency Data Explorer that also points to different internal tools to perform a detailed analysis and the cross-matching between archival catalogs in a multi-wavelength framework.

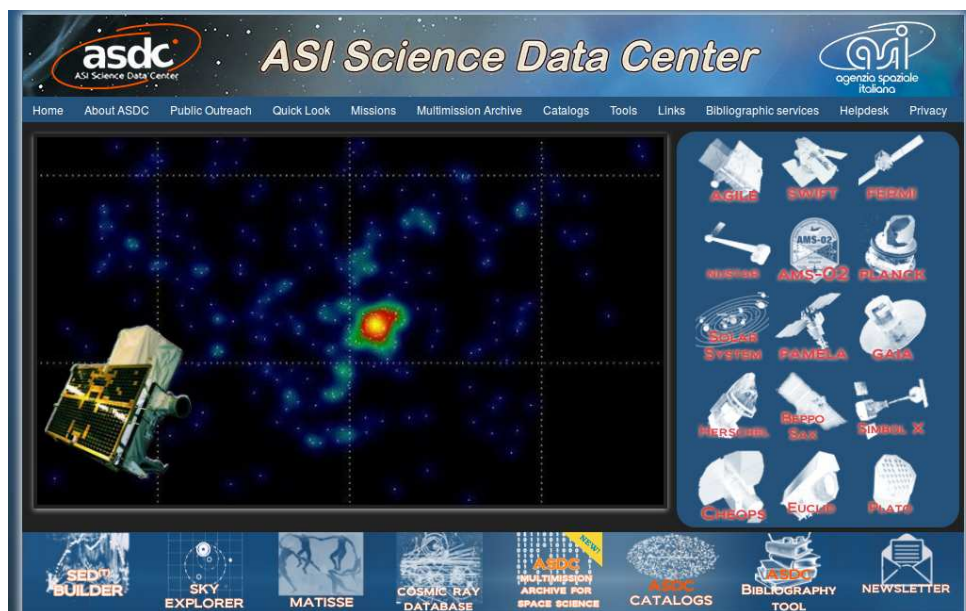


Figure 1. Home page of the ASI Science Data Center - <http://www.asdc.asi.it/>

At present, the ASDC hosts data of the most important current high energy astrophysics missions as Fermi, AGILE, NUSTAR, SWIFT and supports at different level other missions like, GAIA and the astroparticle experiments AMS and PAMELA. Data of past experiments like HERSCHEL, PLANCK and BeppoSAX are also hosted while the possibility to perform queries to external catalogs make possible a complete study of the SED of a specific source through the web-based SED builder tool.

## 1.2 The TeGeV Catalog

The TeGeV Catalog @ ASDC is a catalog of VHE sources observed by ground-based Cherenkov telescopes. The TeGeVcat is collecting all the information publicly available about TeV sources observed by the past generation and current generation of imaging Cherenkov telescopes (Fig. 2). The catalog contains the public light curves data as well as the spectral information that are automatically available in the ASDC SED builder tool (see sec. 2).

The TeGeV catalog currently contains information of 155 VHE sources divided by class types. Default visualization provides information on source name, coordinates and types. Furthermore, threshold energy ( $E_{thr}$ ),

Entry number	Selection mode	LIGHT CURVE	TEV NAME	# OBS.	OTHER NAMES	TYPE	RA (J2000)	Dec (J2000)	INTEGRAL FLUX	THR ENERGY	Distance	Observatory	START TIME
							hh mm ss	dd mm ss	x E-12 cm2/s	[GeV]	z		[MJD]
1	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0006+7259	1	CTA 1/G 119.5+10.2	PWNSNR	00 06 26	+72 59 01	-	-	-	VERITAS	55440
2	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0013-1853	1	SHBL J001355.9-185406	HBL	00 13 52.0	-18 53 29	0.83	310	0.095	HESS	54653
3	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0025+6410	1	Tycho SNR	SNR	00 25 27.0	+64 10 50	0.187	1000	-	VERITAS	54740
4	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0033-1921	1	KUV 00311-1938/RBS 00761RXS J003334.6-192130	HBL	00 33 34.2	-19 21 33.3	-	-	0.61	HESS	-
5	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0035+5947	1	1ES 0033+595	HBL	00 35 16.8	+59 47 24.0	7.1	150	-	MAGIC	55060
6	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0047-2517	2 ▶	NGC 253	Starburst	00 47 34.3	-25 17 22.6	0.56	190	0.000811	HESS	53371
7	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0136+3905	1	RGB J0136+391/B3 0133+388/IRXS J013632.9+390556	HBL	01 36 32.5	+39 05 59.6	-	-	-	MAGIC	-
8	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0152+0146	1	J0152+017/RXJ0152.6+0147	HBL	01 52 33.5	+01 46 40.3	2.7	300	0.08	HESS	54404
9	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0205+6451	1	3C 58	PWNSNR	02 05 31	+64 51 00	0.14	1000	-	MAGIC	56508
10	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0221+3556	1	SJ 0218+35/ B2 0218+35	Blazar	02 21 05.5	+35 56 13.7	-	100	0.944	MAGIC	56861
11	<input checked="" type="checkbox"/>	ASDC Data Explorer	TeV J0222+4302	2 ▶	3C 66A	IBL	02 22 39.6	+43 02 07.8	45	100	0.444	MAGIC	55170

Figure 2. Home page of the TeGeV catalog at ASDC servers - <http://www.asdc.asi.it/tgevcatalog/>.

integral flux above  $E_{thr}$ , distance, name of experiment performing the observation and starting time are provided.

Several other information are optionally available for the visualization by selecting them at the bottom of the web page. Most of them are again extracted by the literature, like:

- the statistical and systematic errors on the TeV centroid position in the sky derived by a 2D-gaussian fit of the TeV excess;
- the differential flux normalization, the normalization energy of the power law differential spectrum, the power-law spectrum spectral index;
- source extension (if present) and orientation;
- observation period and bibliographic references.

Other are derived by a further elaboration of the literature data, like:

- the positional error circle around the TeV source position, calculated by the statistical and systematic errors on the Celestial (or Galactic) coordinates on the TeV excess position.
- integral flux above 1 TeV, calculated by the spectral information extracted from the literature (when available);
- information on source flux variability.

All these information are displayed following the standard ASDC catalog format.

## 2. RELATED TOOLS FOR MULTI-WAVELENGTH ANALYSIS

TeV catalog is fully implemented within the ASDC web tools that allow different possibilities of data exploring and cross-matching with other energy bands. The multi-frequency DATA EXPLORER tool,<sup>3</sup> directly available for each source from the catalog web-page, allows the users to explore the sky region around the source position within a customizable radius and showing neighbour sources belonging to different catalog in radio, infrared, optical as well as X and gamma-rays.

The DATA EXPLORER (Fig.3) tool further provide access to several additional services as the possibility to perform query to both internal and external catalogs and archive as well as it provide the access to different web-based data analysis tools. The full source spectral energy distribution (SED) is than directly accessible trough a dedicated SED Builder tool.

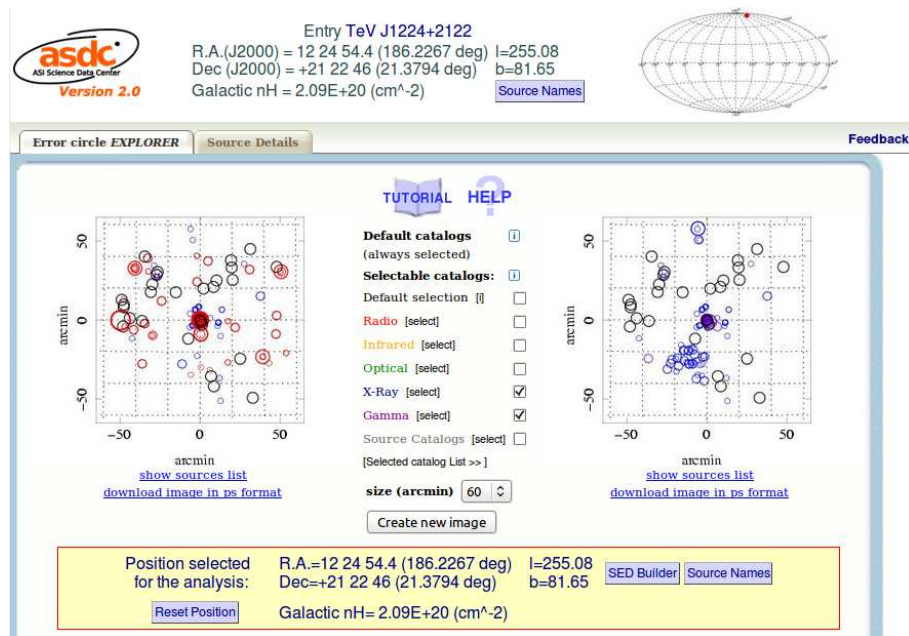


Figure 3. The DATA EXPLORER interface window



Figure 4. The SED BUILDER tool interface

The SED Builder (Fig.4) is a web based program developed at the ASDC to produce and display the SED of astrophysical sources. The tool combines data from several missions and experiments, both ground and space-based, together with catalogs and archival data. Proprietary data can also be properly handled. Based on a Java code and a MySQL database system, the ASDC SED Builder provides different functionalities and several plot options for the analysis of the SEDs.

### 3. CONCLUSION

The ASI Science Data Center is a facility of the Italian Space Agency and it serves as a multi-mission science operations, data processing and data archiving center that provides support to several scientific missions. The ASDC has developed several tools aimed to help the use of its catalogs and database. Within the ASDC framework a VHE source catalog has been recently developed. The TeGeV catalog collects all the information publicly available about TeV sources observed by the Cherenkov telescopes. The catalog is fully implemented within the ASDC web-tools that permit the complete cross-match with catalogs in other wavebands allowing the maximum scientific reward. This will be particularly important in the next future where a significant increase of VHE sources is foreseen thanks to the beginning of the operation of the CTA.

## ACKNOWLEDGMENTS

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