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ROAst: ROot extension for Astronomy

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The ROOT framework is one of the most used software tool-sets for particle physics analysis.The goal of ROAst (ROot extension for Astronomy) is to extend the ROOT capabilities adding packages and tools for astrophysical research bridging the gap between particle physics and astronomy. The focus is on the integration of astronomical catalogues and on the support for astronomical coordinate transformations, manipulations as well as the graphical representation of astronomical regions.

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1. Introduction

ROOT [1] is a modular scientific software and library developed by CERN mainly designed for particle physics data analysis. Indeed, ROOT provides functionalities needed to handle large data processing, statistical analysis, visualisation and storage. Moreover, it provides platform independent access to the graphics subsystem and operating system using abstraction layers. Parts of the abstract platform are: a Graphical User Interface, a GUI builder, container classes, a command line interpreter (CINT in version 5, CLING in version 6), object serialization and I/O management. ROOT is mainly written in C++ but integrated with other languages such as Python and R. The ROAst project has been developed in the ASTERICS task 3.4 (Data ANAlysis/interpretation, D-ANA) [2] that is focused on two main themes: tools to analyse and interpret astronomical/astroparticle observations in an efficient manner and tools for accessing these observations in an appropriate way, allowing efficient remote and distributed analysis. The ROAst package extends the functions of the ROOT framework adding features that are needed in astroparticle physics and astronomy. In particular, access to offline and online catalogues of astronomical objects is made simple through a single API that represents data from different sources in a uniform way, which boosts research effectiveness, data exchange and open access. The software underwent code review and quality improvement driven by the support with the KM3NeT Software Group [3].

2. ROAst Overview

Currently, ROAst comes with four main feature sets implemented in order to supply:

- access to astronomical catalogues;
- astronomical and time coordinate conversion tools;
- graphical tools to produce commonly used plots (general and partial sky-maps);
- high-precision Moon and Sun position relative to the Earth.

In order to speed up future extensions to the catalogue system, the general architecture relies on an intermediate abstraction layer and all the catalogue implementations share the same methods simplifying the access. Catalogue querying can be done extracting regions of various shapes (rectangles, circles, ellipses) around each object. All extraction methods (Fig.1) support equatorial, galactic, ecliptic, horizontal astronomical coordinates (using Latitude/Longitude or UTM as geographical coordinates). Various astronomical coordinate are complemented with a full set of methods for mutual transformations that can be applied directly on the extracted region or on some user supplied coordinate. Time conversion methods are also provided (i.e. Gregorian date to Julian date and *vice versa)* .

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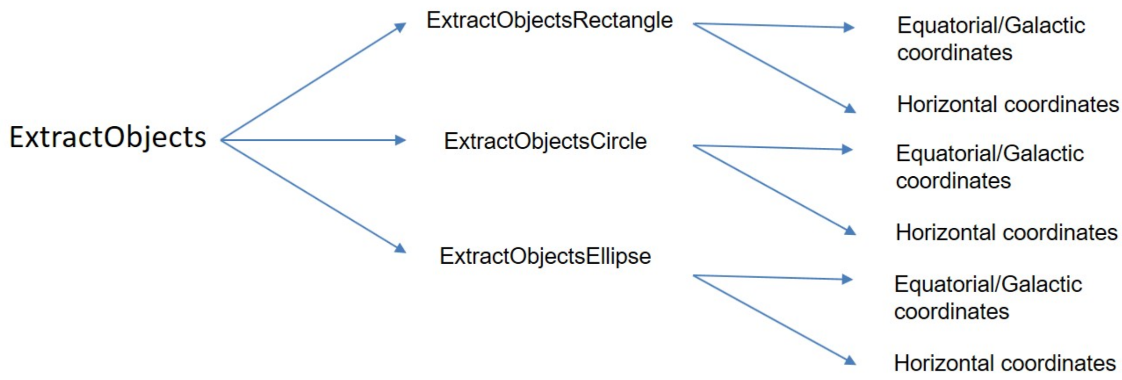

Fig. 1: Scheme of the extraction methods.

The extracted astronomical objects are stored in the public vector *ObjectsCollection* and using the *Print* method it is possible to describe all the objects in the region or one single astronomical object in human-readable way.

ROAst provides seamless access to two local catalogues, namely UCAC4 (U.S. Observatory CCD Astrograph Catalog 4) and URAT1 (U.S Robotic Astrometric Telescope 1) and to the VizieR on-line catalogue repository and all the VO (Virtual Observatory) compliant catalogues. The Virtual Observatory is an international community (composed by institution such as Euro-VO, MAST, GAVO, VAO, IVOA) which aims to supply on-line access to the available astronomical data archives of ground and space-based observatories setting the international standards for data format and data access. Moreover, the VizieR services provide an extensive on-line library of astronomical catalogues, tables and associated data, accessible via multiple interfaces. Query tools allow the user to select relevant data tables and to extract and format records matching given criteria. Currently, VizieR supplies 17621 catalogues available from CDS (Centre de Données astronomiques de Strasbourg) of which 16999 are available on-line.
Finally, ROAst features an implementation of precise Sun and Moon motion. The position methods adopt the ELP-2000-82 (Moon) and VSOP-87 (Sun) models for the calculation.

2.1 ROAst Graphics

The ROOT graphical capabilities are complemented with new graphs that include Aitoff projection and SkyMap, well integrated with the catalogue access features. Coordinate conversion tools support usage of data in diverse scenarios. The aim is to supply a basic set of graphical tools fully consistent with the ROOT environment. User customization of the plot is possible. The main graphical methods are: *Draw/DrawFeature,* which draws the astronomical objects positions; *DrawAitoff,* which can be used to represent the astronomical objects using the equatorial Aitoff projection (Fig.2); and *DrawSkyMap* for the whole sky-map using equatorial Aitoff. A decreasing Right Ascension axis in the graph can be enabled by toggling a flag.

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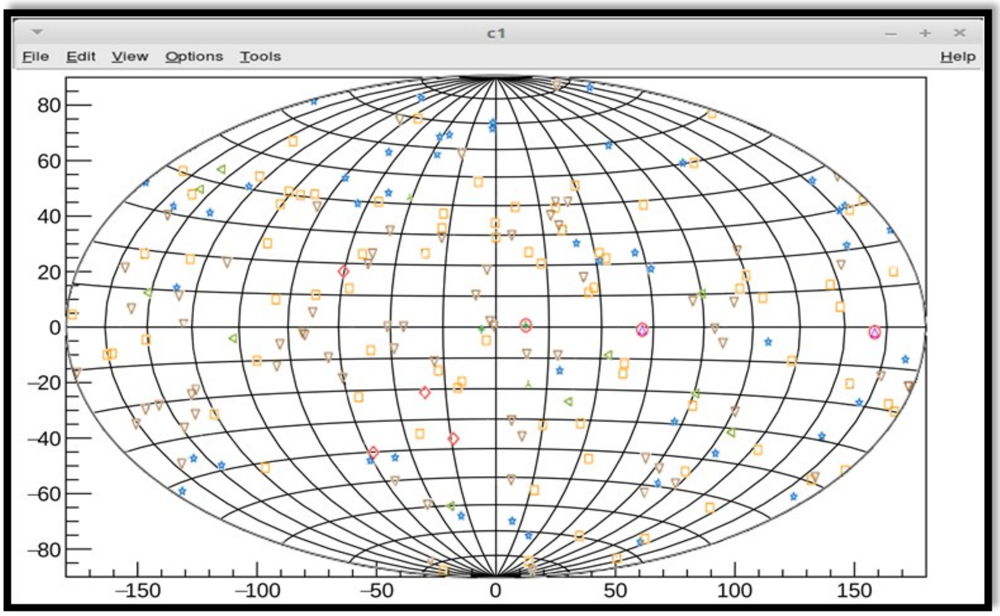

Fig. 2: Plot, obtained using DrawSkyMap method, of different astronomical sources (SNR, Pulsar, Blazars, etc…) extracted from the Hard Fermi-Lat catalogue in equatorial coordinates.

The *Draw* and *DrawFeature* methods support equatorial, galactic and horizontal astronomical coordinate system.

3. ROAst example

Fig. 3 shows a use-case in which the user extracts a circular region from an on-line Virtual Observatory via the *VOCatalogue::ExtractObjectCircle* method. After the extraction, the space region is plotted using the *Draw* method and the second magnitude is plotted using the *DrawFeature* method. A C++11-compliant compiler is required, as well as ROOT 6 and the *libcurl* library, in order to use ROAst. Limited support is also available for ROOT 5, i.e. without ROOT dictionaries.

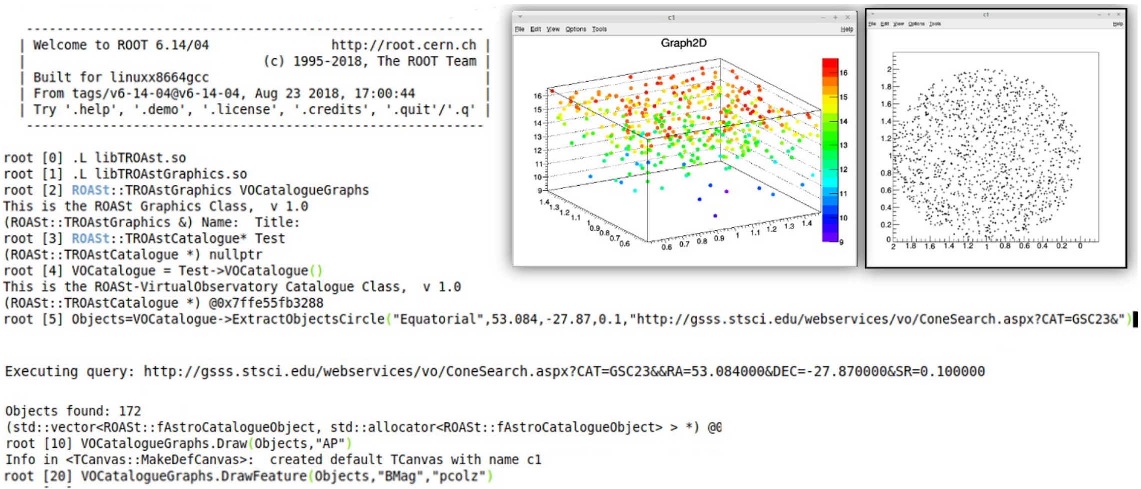

Fig. 3: Example of region extraction from an on-line catalogue and the subsequent plotting of the circular region and of the second magnitude.

4. Conclusions and perspectives

An updated version of ROAst, with an improved set of graphical tools and fully tested coordinate transformation support, is ready and can be found at https://gitlab.com/spisso/ASTERICS-ROAst. ROAst provides a convenient and easy way to import tools from the astrophysics community in the high-energy physics workflow. The next planned developments of ROAst are: improving the classes for coordinate manipulations (rotations and translations), adding methods for the positions of the major planets, adding support for image catalogues and allowing asynchronous on-line query (TAP calls). In the future it is planned to propose ROAst as a standard package for ROOT or derivative analysis frameworks.

5. Acknowledgment

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