TRANSIENT ASTRONOMICAL PHENOMENA MONITORING WITH ASTRO-COLIBRI

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Abstract. Time-domain astronomy consists of observing and studying the most violent transient cosmic phenomena, such as tidal disruption events, supernovae, gamma-ray bursts, neutrinos and many other sources of a large variety of radiation and particles. The detection of a new transient event needs to be communicated very rapidly among astronomers and astrophysicists to allow them to conduct their follow-up observations. This paper presents astro-COLIBRI, a real-time platform that evaluates alerts sent by observers regarding transient sources.

Keywords: Time-domain astronomy, Transient sources.

1 Introduction

For nearly 500 years, astronomical observations were synonyms of astronomical observations in the visible domain. The exploration of the Universe was limited to the [400; 800] nm range of the electromagnetic spectrum. Last century, astrophysics underwent fundamental changes with the multi-wavelength astronomy era, opening new observational windows for studying high-energetic transient cosmic phenomena. Transient cosmic phenomena are short-lived and unpredictable, and the most energetic events in the Universe, burning brightly and fading away. They include flares of Active Galactic Nuclei (AGN), Tidal Disruption Events (TDEs), supernovae explosions, Gamma-Ray Bursts (GRBs), black holes or neutron stars collisions, and many other radiation sources and particles. An extensive network of observers follows these phenomena. We can cite, for instance, the IceCube neutrino detector, the Swift and Fermi satellites observing mainly GRBs, or the LIGO and VIRGO observatories aiming to detect gravitational waves (GWs). The short life span of cosmic events, from a few seconds to a few days only, requires rapid processing and analysis of the information to perform follow-up observations. However, time-domain astronomy faces two challenges: the multiplicity of platforms to access information and the increasing amount of data generated. Indeed, in time-domain astrophysics, each community uses dedicated platforms according to the discoveries that interest them. For instance, the Gamma-Ray Burst Coordinates Network (GCN[*]) platform is dedicated mainly to the gamma-ray bursts astrophysicists community Barthelmy et al. (1995). The Astronomer's Telegram (ATel[†]) is a communication channel where observers report discoveries regarding a large variety of astronomical sources (black holes, blazars, neutron stars) Rutledge (1998). The Transient Name Server (TNS[‡]) is another platform mainly dedicated to confirmed supernovae candidates. Furthermore, additional and complementary information is present in astronomical databases and catalogues such as NED[§] or SIMBAD[¶]. The multiplicity of the platforms used and the increasing volume of alerts sent by observers make it impossible for astrophysicists to read, analyse and trigger their follow-up observations in time. Thus, new efficient ways of handling information are needed to tackle the challenges of gathering and analysing

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[*] `https://gcn.gsfc.nasa.gov/`
[†] `https://astronomerstelegram.org/`
[‡] `https://www.wis-tns.org/`
[§] `https://ned.ipac.caltech.edu/`
[¶] `https://simbad.unistra.fr/simbad/`

information in real-time from various data sources. To assist amateur and professional astronomers in their decision-making, we developed a new tool: the COincidence LIBrary for Real-time Inquiry for Multimessenger Astrophysics (astro-COLIBRI). This paper presents the real-time tool astro-COLIBRI, providing a graphical representation of the most relevant information to the whole astronomers' community.

2 Listening and Centralising Information in Real Time

Figure 1 illustrates the multimessenger alert pipeline. As introduced earlier, an extensive network of astronomical facilities observe the Universe for new transient sources and report their observation via different channels. Alerts sent by observers are listened to by astro-COLIBRI, which links and gathers information from the various external sources for processing, and notifies the application's users by providing a synthesised version of all relevant information regarding a transient. Thus, astro-COLIBRI is a central point for accessing information

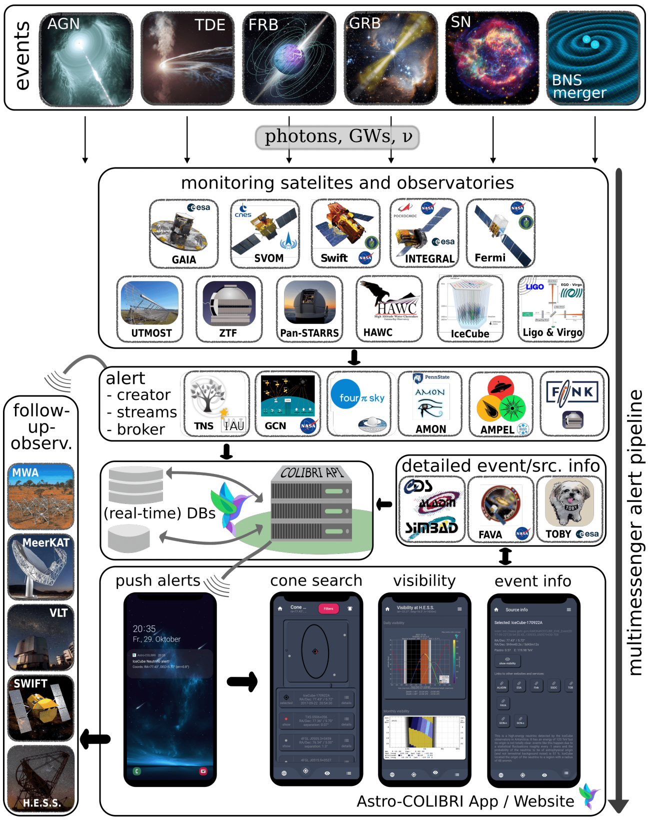

Fig. 1. Alert pipeline of astro-COLIBRI

about astrophysical sources and transient events. The central point of astro-COLIBRI's architecture is the Representational State Transfer (RESTful) API built using the Python's Flask[‖] framework and hosted on the Heroku[**] cloud-computing service.

3 Graphical Interface to Summarise Information

To inform users most efficiently and to offer a modern and mobile use, we developed Astro-COLIBRI user interfaces independent of the platform used. Then, using the open-source framework Flutter[††], we developed a website[‡‡] version and an smartphone version for iOS and Android.

[‖]https://flask.palletsprojects.com/en/2.0.x/
[**]https://www.heroku.com/
[††]https://flutter.dev/
[‡‡]https://astro-colibri.com/#/

3.1 Information on Latest Detected Transients

Figure 2 illustrates the web interface of astro-COLIBRI. The main window is a representative map of the

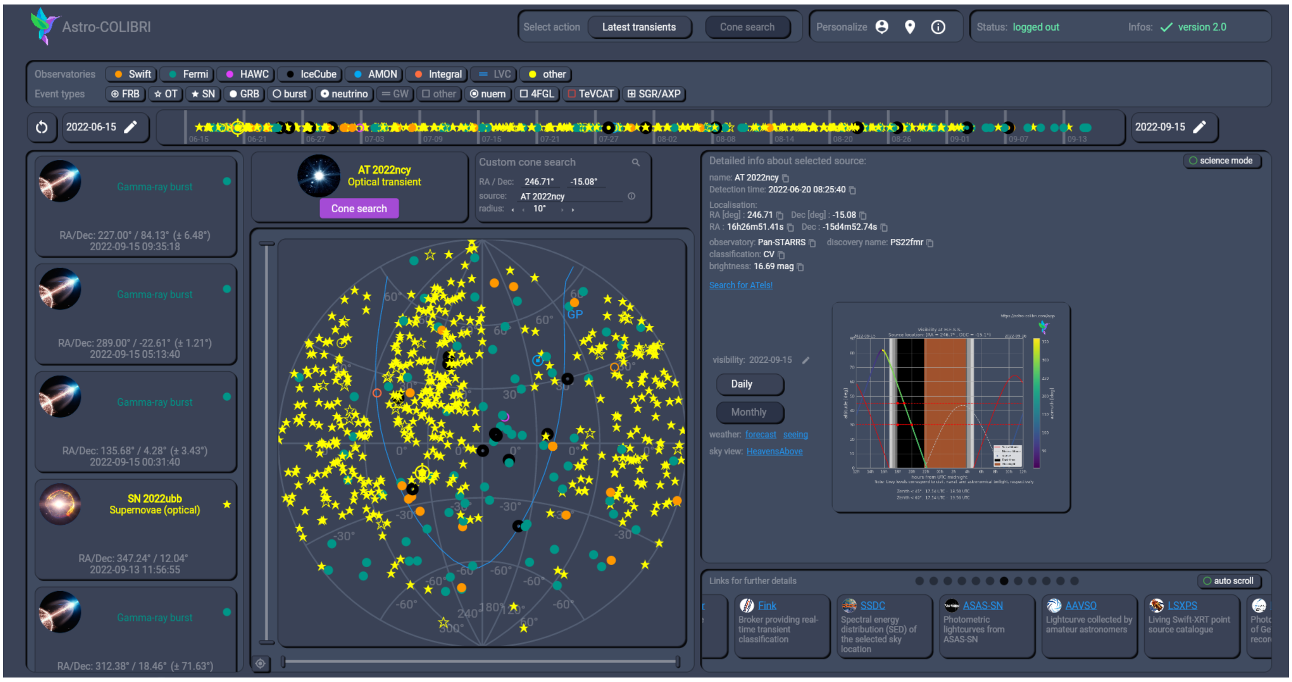

Fig. 2. Web interface of astro-COLIBRI V2.0.

Universe with the various transient events detected on a temporary scale (definable by the user). In addition to selecting the time scale, the user can apply filters regarding events' types and observatories. The window on the right provides the primary information regarding the transient selected on the map: coordinates, date of detection, magnitude, and observatory involved in the observation. We also point to external official data sources: observation reports (GCN, TNS, Atel), astronomical databases, or (according to the nature of the event) provide the light curves via FAVA* links. In the current version of astro-COLIBRI, the Web interface has evolved to allow the application to be used by all users: professional and amateur. Indeed, there are two new modes: a "science" mode and a standard version for non-experts. The science mode contains more detailed information, with the display of the visibility plot in particular (Section 3.2) and meteorological information above the observatory. The standard mode contains general information about the selected event and points to external pages (*e.g.* Wikipedia), clarifying the event's nature. In addition, we provide links to discussion forums, such as VSNET, to allow amateur astronomers to share their observational information.

3.2 Cone Search and Graphical Representation of Visibility

The possibility to make a cone search is one of the main functionality in astro-COLIBRI. It allows the representation of an event in the context of other known events or sources in the relevant temporal and spatial phase space. Figure 3 below illustrates an example of cone search. Users can automatically perform a cone search by typing the event's coordinates or the designation. An auto-completion feature helps the user to find the requested event in astro-COLIBRI's database (implemented after amateur astronomers' feedback). A second key feature of astro-COLIBRI platform is the graphical representation of the eventual observability time window for a selected transient at a given observatory. We added a new feature allowing amateur astronomers to obtain the visibility plot by giving their location. Figure 4 is an example of the visibility plot computed by the API for the next 24 hours of the AT 2022ncy optical transient at the H.E.S.S. observatory (Namibia). The left y-axis corresponds to the altitude (in deg) of the Sun (red), Moon (in grey) and the selected source. The right y-axis

*https://fermi.gsfc.nasa.gov/ssc/data/access/lat/FAVA/LightCurve.php

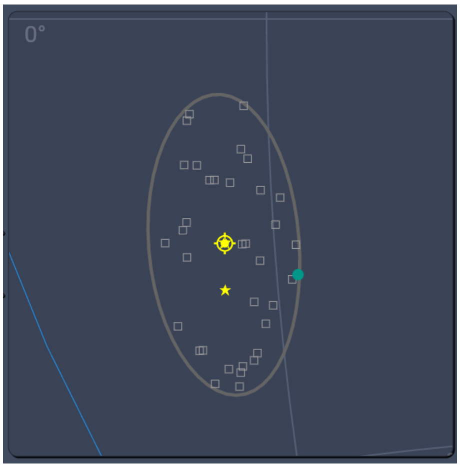

Fig. 3. Cone search around the optical transient AT 2022ncy.

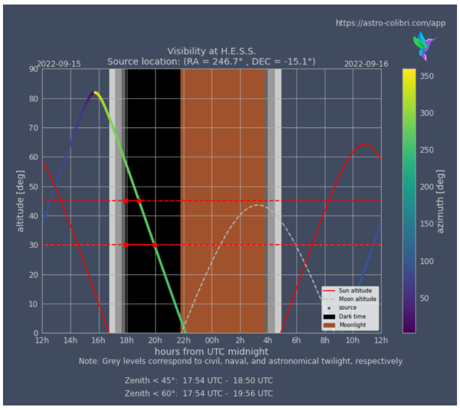

Fig. 4. Visibility plot of AT 2022ncy optical transient at the H.E.S.S. observatory.

corresponds to the source's azimuth (in deg). Exact observation conditions (including Moon time, the different levels of twilight[†]: civil, naval and astronomical) are implemented for each desired observatory.

3.3 Real Time Alerts on Mobile Devices for Transient Events

For mobile use, astro-COLIBRI sends notifications via the cloud-based Firebase Cloud Messaging (FCM) service. For instance, based on users' preferences regarding specific event classes *e.g.* neutrinos, supernovae, GRBs or optical transients, astro-COLIBRI sends push notifications to notify users about the latest event of interest. Thus, opening the application, the mobile interface provides a graphical representation with a summary of the relevant data.

4 Conclusion

Initially created by professionals and for professionals, astro-COLIBRI is today usable and adaptable to the needs and uses of amateur astronomers. Since the development of astro-COLIBRI, we have implemented several new features adapted to the needs of amateurs: the addition of optical sources, autocompletion, and the possibility to choose one's observation coordinates. Adding a scientific and standard mode allows more straightforward navigation and exploration. To respond the needs of the astronomers' community, the astro-COLIBRI development team is welcoming comments and feedback to further improve the platform. Contact: astro.colibri@gmail.com

[†]`https://www.weather.gov/lmk/twilight-types`

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