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RAPAS, PRO-AM NETWORK FOR THE SCIENTIFIC ALERTS, 2023 STATUS

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Abstract. This is an update of the RAPAS project introduced last year during " Les Journées de la SF2A 2022" (Thuillot et al. 2022). Several projects on the ground and space are releasing all along the years alerts (ZTF, ASSAS-SN, ATLAS, CRTS,...). Gaia mission is the most emblematic example delivering Solar System Objects (SSO) new detections (Carry et al. 2021), Galactic or extragalactic variable alerts (Hodgkin et al. 2021). In addition, during the last years, other programs are transient events in the multimessenger domain (GW, GRB, X, Neutrinos, FRB,...) (Schüssler et al. 2023) where the optical counterpart is to be find in the field of the assumed designation accuracy. The RAPAS ProAm collaboration, funded by Paris Observatory in the frame of the multi-year Incentive Action Pro-Am (AIP), invited amateur french observatories to register to the RAPAS Gemini web site* all along 2022 and 2023 years. End of 2022, we equipped them with 25 set of filters we designed and manufactured meeting the three Gaia photometric spectral bands : G, Gbp and Grp. We are assessing the upper magnitude limit and the magnitude accuracy of each amateur observatory. In 2023 we are launching the design of two spectrograph prototypes able to deliver Spectral Emission Distribution (SED) of each detected alert to allow its first classification and characterization or reject false alerts. We are on the way to the 2024 and third year of the program to release an operational Pro-Am network.

Keywords: Gaia, Photometry, Astronomical Alerts, Transient Event Detection, Filters, Spectral Energy Distribution

1 Introduction

Observational programs generating astronomical alerts are increasing. These could be in a wide range of objects and signatures from new Solar System Objects (SSO), to Galactic Novae or eruptive stars, or even beyond to high energy transient events, far away in the deep extragalactic cosmos as Supernovae or Gamma Ray Bursts. These alerts are released either with optical instruments or with non optical surveys. In the case of optical

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*RAPAS Gemini web page : `https://proam-gemini.fr/rapas/` (in French) data, the RA and Dec are usually accurately delivered except for SSO, where latencies between observations and inaccuracies in orbit model building provide a wider and wider field of research to recover it. In the case of non-optical alerts these could be released from Gamma ray or X ray space observatories, Cosmic ray and Neutrino detectors, Gravitational Waves Interferometers, or Radio waves telescopes. Inherent to the signal natures and related instrument, a wide inaccuracy basket is attached to the angular designation of the source, usually from 1 square degrees to several 10 square degrees, or even more ! Therefore, wide field of view and high magnitude upper limit optical instruments are required to find and classify optical counterparts. This is a task where amateurs with their availability and their networked instruments can efficiently contribute to the discovery of transient phenomenon and why we launch the RAPAS[†]. project in 2022.

The monitoring of the phenomenon can then, be carried out by amateurs or mobilize large professional instruments thanks to this Pro-Am collaboration and organization.

2 Filter design and manufacturing

Gaia is releasing a very accurate catalog since 2016 with DR1 (Data Release 1), in June 2022 we got the latest update Gaia DR3, then Gaia DR5 is scheduled in 2028, and beyond the final release. This catalog deliver accurate 1.9 10^9 stars angular localization and photometric measurement thanks to the ideal space probe localization. The magnitude native measurements don't need any atmospheric corrections. Gaia introduce three interesting photometric bands: G, Gbp and Grp (Riello et al. 2021) given on Fig. 1.

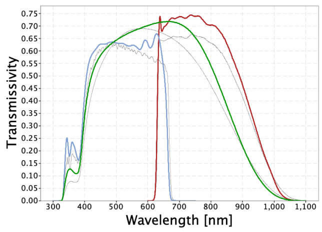

Fig. 1. Gaia photometric bands G band in green, Gbp in blue, Grp in red

Before the RAPAS program we try to purchase the filters defining these very interesting bands. With these large bandwidth compare to standard UBVRI Johnson Cousins set, or Bessel filter set or ugriz set from the SDSS, we enhance the sensitivity of amateur telescopes. In using Gaia bandwidth we will be able to perform accurate photometric reductions in using the Gaia catalog. We realized in fact these filters does not exist. The Gaia G, Gbp, and Grp band are resulting of the resistivity and thickness giving the quantum efficiency of three families of back-side illuminated CCD on the Gaia focal plane array, combined with a small prism for the Gbp and Grp bands. The Gaia team gives us the feedback that such filters never had been realized. In the framework of this project, proposed to Paris Observatory AIP fundings, we designed and manufactured such fitted filters in taking into account the spectral sensitivity dispersion we meet with amateur CCD or CMOS cameras and variables air mass. At the end of 2022 we got the delivery of 25 set of the three filters we call A, B and C displayed on Fig. 2 with the effective spectral transmission on Fig. 3. These filters are 2mm thick and 50mm in diameter.

Fig. 2. picture in transmission of the three filters A, B and C from left to right

3 RAPAS network

With the first public presentation of the RAPAS project during the "2022 journées de la SF2A" (Thuillot et al. 2022) we invited amateurs to join our team and to register their observatory on the Gemini web site on the

[†]`https://rapas.imcce.fr` (in French)

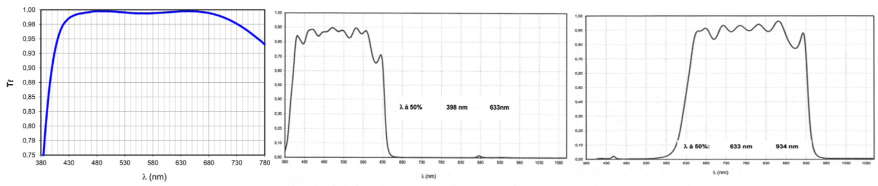

Fig. 3. Spectral transmission curves of the three filters A, B and C from left to right

RAPAS topic‡. More than 30 observatories registered in october 2022 for our first workshop§ where we share the detail of RAPAS project and how we will implement the characterization of the instrument set up equipped with the RAPAS set of filters. In September 2023 we are close to 50 observers registered. During this workshop we start the attribution of the 25 set of filters. Fig. 4 shows the location of the equipped observatories giving a wide spread over France to meet wide range of Longitudes and Latitudes and meet independent cloud coverages if any. The range of telescope diameters are from 200mm to 820mm.

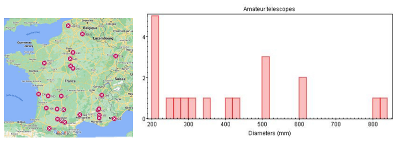

Fig. 4. French localization of the observatories equipped with RAPAS filters. The range of telescope diameters is from 200mm to more than 800mm displayed on the histogram on the right.

4 First photometric acquisitions

Step by step each observers perform the mounting of the filters. Due to the fact filters installations rely on various optical and mechanical interfaces this could be more or less easy. During the workshop we provide three fields of view from the Sky and Telescope paper (Everhart 1984) defining SA51, SA57 and SA68. It allows all along the year to get one of these field passing the meridian during the night. M. Serrau produced the Grappa catalog¶. This is an extract of EDR3 Gaia catalog limited to all information necessary for astrometric and photometric reductions. In addition M. Serrau provides a process in using Prism V11 and Grappa catalog to extract and compare in any field the star flux with the Gaia catalog. This allows the construction of graph showing the fidelity between the measured flux with the filters A, B in C in versus the magnitude in respective G, Bbp and Grp bands. The standard deviation versus the magnitude is assessed. Several observers demonstrate upper limit magnitude above 20.

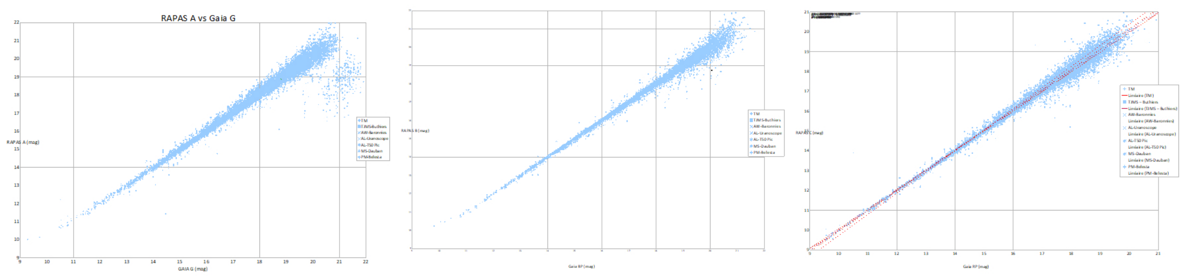

Fig. 5. Example of the data reduction of the measured flux with A, B, C filters vs respective G, Gbp, Grp (courtesy M. Serrau)

‡see https://proam-gemini.fr/rapas (in French)
§see `http://rapas.imcce.fr/RAPAS-atelier1.html` (in French)
¶see `http://www.astrosurf.com/noctambule/CCD-GRAPPA/`(in French)

Mid of may 2023 we got the alert of a supernova discovered in M101 : SN2023ixf. This gives us a good opportunity to mobilise the starting RAPAS network on real case. It shows how, all along the weeks, the operational observers are available to acquire the field and to realise the data reduction. The Fig. 6 show the light curves got with A B C filters and reduced with Gaia catalog in respective G Gbp and Grp versus time. We deliver also the curve of the G magnitude vs the colour index Gbp-Grp showing how the equivalent temperature of the source decrease with the magnitude.

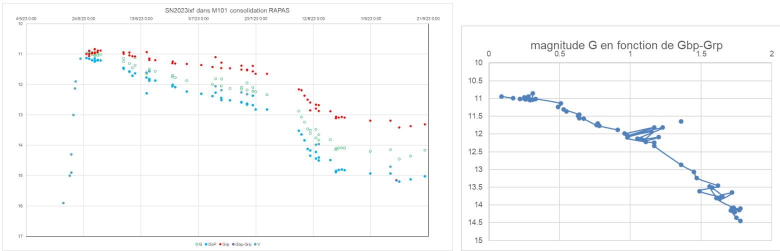

Fig. 6. left light curve of the SN2023ixf discovered in may 2023 in M101. Red dots for Grp magnitude got through filter C, green empty dots for G magnitude through filter A and blue dots for Gbp magnitude through filter B. Right G magnitude vs colour index Gbp-Grp

5 Spectral Energy Distribution

In 2023 we launch the spectroscopic task of the Rapas project. The purpose is following the detection and localization of an optical counterpart candidate to be able to provide a first characterization of the signature in getting the spectral energy distribution. We need to show how deep we may get this spectra with magnitude range up to 20. Therefore the trade off of such spectrograph have to limit the Resolution around 100 to get the targeted sensitivity. We have just launched the manufacturing of two prototypes relying on existing spectrograph Alpy 200 and StarEx VLR. On the Alpy 600 we replace the grism for a transmission blazed grating of 200 grooves per millimeter, giving an Alpy 200. And the Star'Ex we replace the reflective grating 600g/mm with a 150g/mm one's. We schedule to assess the limiting magnitude and the effective resolution before the end of this year to allow according the target be able to detect : continuous spectra fitted to a Blackbody with a temperature measurement, continuous spectra not fitted to a Blackbody signature, monitor the temperature variability of the target, emission lines on the spectra, wide absorption lines, localize Balmer or Lyman lines break to get the target z, ...

Fig. 7. Alpy and Star'Ex spectrograph on the left and on the right

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