The Farid & Moussa Raphael Observatory

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Abstract. The Farid & Moussa Raphael Observatory (FMRO) at Notre Dame University Louaize (NDU) is a teaching, research, and outreach facility located at the main campus of the university. It located very close to the Lebanese coast, in an urbanized area. It features a 60-cm Planewave CDK telescope, and instruments that allow for photometric and spectroscopic studies. The observatory currently has one thinned, back-illuminated CCD camera, used as the main imager along with Johnson-Cousin and Sloan photometric filters. It also features two spectrographs, one of which is a fiber fed echelle spectrograph. These are used with a dedicated CCD. The observatory has served for student projects, and summer schools for advanced undergraduate and graduate students. It is also made available for use by the regional and international community. The control system is currently being configured for remote observations. A number of long-term research projects are also being launched at the observatory.

1. Introduction
The Farid & Moussa Raphael Observatory was inaugurated in July 2013. The observatory was initially conceived with the start of a joint masters degree in astrophysics between NDU and Université St-Joseph, two private Lebanese universities. The initial proposal meant to develop a versatile facility capable of assuming many roles. It was designed to serve outreach activities like school and general public visits during observing nights, education in undergraduate, and graduate classes, as well masters theses work. The observatory was meant to be suitable for research projects, since small observatories are considered important in long-term monitoring of variable and transient phenomena. We also aimed at building a cost effective facility. Most of the selected options were based on these essential constraints, knowing that the FMRO was to be built on campus. A gift by Mr. Gilbert Chaghoury helped finance the purchase of equipment and construction costs. The location of the observatory is provided in table 1. It is in continual development as we are constantly improving on its operations, as well as adding to our set of instruments and/or software suites. In what follows we will describe the equipment of the observatory, showcase some of the work done by students, and conclude with future prospects.

2. Equipment
2.1. Telescope and mount
The Observatory is centered around a Planewave CDK24, a corrected Dale-Kirkham Astrograph telescope, with a diameter of 61 cm and a focal ratio of 6.8. The telescope provides for a 70 mm corrected field of view, equivalent to 58 arcminutes. Instruments are attached to a 3.5 inch,
Table 1. Basic geographical data of the FMRO

|                |          |
|----------------|----------|
| Latitude       | 33° 56' 58.54" N |
| Longitude      | 35° 36' 31.61" E |
| Altitude       | 149 m    |

temperature compensated, Hedricks focuser at the back-end. The telescope is mounted on a Astro-Physics 3600GTOPE german equatorial mount, equipped with high-precision encoders. Initial work have shown that the setup allows for unguided 5-minutes exposure for objects at relatively large altitudes. The system is housed inside a Technical Innovations 15 feet ProDome. The dome may be slaved to the telescope. Figure 1 shows the telescope on the mount, and the building and dome of the FMRO.

Figure 1. The Planewave CDK 24 on the Astro-Physics 3600GTOPE mount at the FMRO, and a view of the building and dome

2.2. Instruments

The FMRO is currently equipped for photometry and imaging, and spectroscopy. The main imager is an Apogee Alta F-42 camera equipped with a 2k×2k thinned, back-illuminated, e2V CCD chip. It has $13.5 \times 13.5 \mu m^2$ pixels, for a total imaging area of $27.6 \times 27.6 \mu m^2$. The field of view of the camera is $23' \times 23'$, with a scale of 0.68"/pixel. The camera is housed in Apogee’s deep cooling housing, D9. It is thermo-electronically cooled up to a temperature of 60°C below ambient [1]. The observatory possesses two sets of photometric filters: the Johnson-Cousins UBVRI [2] [3], and the Sloan u’g’r’i’z’ [4]. These are 50mm Astrodon square filters [5]. They are mounted on two carousels to be used with the Optec Inc IFW-3 filter wheel [6].

Spectroscopy at the FMRO is served by two spectrographs, both designed and built by Shelyak. They were designed as part of a pro-am collaboration. We have the Littrow high resolution spectrograph, LHIRES III, with 5 gratings: 2400, 1800, 1200, 600, and 300 l/mm. With the 2400 l/mm gratings, the instrument provides for a resolution $R = 17000$ at Hα. The second spectrograph, eShel, is a fiber-fed visible echelle spectrograph covering the wavelength range $450 \mu m \leq \lambda \leq 700 \mu m$. The resolution averages 12000 over the whole wavelength range [7].
A Santa Barbara Instruments Group STT 1603ME CCD camera is dedicated for spectroscopy. The CCD is a Kodak KAF-1603 sensor with $1536 \times 1024$, $9 \times 9\,\mu m^2$ pixels.

3. Students Projects

The FMRO have been used extensively for graduate student work, mostly within a course on observational astrophysics. Projects from the detection of the transit of an exoplanet to the determination of the type of a suspected variable, or CMDs of open clusters have been attempted or completed. We present three examples of students projects done with the FMRO.

Figure 2 shows the first visible light CMD of the open cluster, Dolitze 9. Based on data obtained at the observatory, and other from the literature, one graduate student is completing his master thesis on the cluster.

![Figure 2](image)

**Figure 2.** The first CMD of Dolitze 9, a sparsely populated open cluster

HD 133159 is listed as a suspected variable. A graduate student plans to try to identify its type. Figure 3 shows a preliminary light curve of the object. The night during which data was obtained was not photometric. Magnitudes are based on differential photometry using a single comparison star.

KOI 1150 is from the catalog of Kepler objects of interest. Its transit was observed at the FMRO for the course project of another graduate student. The star, K1150.01 has a Kepler magnitude of 13.326. The exoplanet orbits the star in 0.677375164 days and the transit duration is 1.8243 hours. Figure 4 shows the light curve obtained at the FMRO. Error bars are inaccurately reported by the student.

Most recently, the observatory has registered with the Gamma-ray Coordinates Network to begin contribution to GRB follow-up observations.

4. The Future of the FMRO

Although located in a light polluted area, about 15 kilometers to the north of the Lebanese capital, Beirut, and in an urbanized area, the FMRO have shown potential to produce interesting
Figure 3. Light curve of HD 133159 in the V band from differential photometry, based on one night of observations.

Figure 4. Transit of the exoplanet orbiting K1150.01 from the Kepler Objects of Interest.

work in the areas for which it was developed. Although all of the examples shown are photometric projects, the two spectrograph have been successfully tested on the telescope. Future work will develop also around spectroscopy. We are also developing polarimetric capabilities with the development of BeePol [8].

We are also developing appropriate controls and selecting software interfaces to be able to make the observatory available to remote observations. We also plan to explore automated observations with the aim of achieving robotic operation for parts of the year. The observatory, in that regard, is considered a test bed for the future operation of a planned observatory to be installed on a mountain site.

References
[1] URL http://www.andor.com/pdfs/specifications/Apogee_AltA_F42_Specifications.pdf
[2] Johnson H and Morgan W 1953 ApJ 117 313
[3] Cousins A 1976 Monthly Notices of the Astron. Soc. Southern Africa 35 70
[4] M Fukugita T Ichikawa J G M D K S and Schneider D 1996 AJ 111 1748
[5] URL http://www.astrodon.com/index.html
[6] URL http://www.optecinc.com/astronomy/catalog/ifw/ifw-3.htm
[7] Eversberg T 2016 PASP 128 1
[8] Hajjar R and Wehbe B 2017 Frontiers in Theoretical and Applied Physics 2017 (J. of Phys. Conf. Series)