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The Fleming Survey: High-cadence survey for variable stars in the northern Galactic Plane

Aleks Scholz ,[1] Ben Warwick,[1] and Thomas van Aalten[1]

[1] *SUPA, School of Physics & Astronomy, University of St Andrews, North Haugh, St Andrews, KY16 9SS, United Kingdom*

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ABSTRACT

We present first results from the Fleming Survey, a high-cadence search for variable stars in the northern Galactic Plane, conducted with the James Gregory Telescope in St Andrews (UK). After observing twelve fields, each over a timespan of 3-5 h and with a cadence of 1 min, we identify 8 variable stars with clear periodic flux modulation in our lightcurves. Two of these are deemed to be δ Scuti pulsators, five are most likely eclipsing binaries. For most of our discoveries, the variability is known in the literature, but the exact period and shape of the lightcurve is not. This mini-survey demonstrates that high-cadence observations with small telescopes are a useful complement to ongoing and planned massive variability surveys.

1. INTRODUCTION

Most existing variable star surveys aim to find stars that are variable on timescales of days and longer. In recent years a few projects have been initiated to probe shorter timescales of minutes, including (but not limited to) OmegaWhite (Macfarlane et al. 2015), the DECAM Minute Cadence Survey (Dame et al. 2019), and the ZTF high-cadence Galactic Plane survey (Kupfer et al. 2021). The Fleming Survey is another project with this goal, specifically set up to search for and characterise stellar variability on short timescales. For this purpose, the survey is observing fields in the northern Galactic Plane, using the almost 60 year old James Gregory Telescope (JGT) in St Andrews/UK. We report first results of the survey in this Research Note.[1]

Given the relatively modest aperture of our telescope and the site near sea level, the Fleming Survey is expected to find primarily relatively bright variable stars, most commonly eclipsing binaries and pulsating variables. We expect that most of our discoveries will be known to the literature, but many will not yet have a high-cadence, high signal-to-noise lightcurve. As unbiased survey, we also expect to be able to constrain the frequency and the parameter range of specific types of variables. Spectroscopic follow-up of variable stars will complement the imaging survey in the future.

2. FLEMING SURVEY: OBSERVATIONS AND DATA REDUCTION

The JGT is the largest Schmidt-Cassegrain telescope in the world, with an 38" primary mirror and a 37" corrector plate, but is used at a reduced aperture of 33". It is located on the campus of the University of St Andrews, inaugurated in April 1962. The telescope is primarily used for teaching and outreach, and is operated mostly by students. The observations reported here were obtained with a Starlight Xpress Trius SX36 camera, with 2×2 binning, resulting in a image scale of 1.0 arcsec/pixel and a full field of view of 48×32 arcmin. All observations are in white light, without filter.

For the Fleming Survey, we observe fields at galactic latitude of 0 deg that are well visible at a given night at our location. For each field, we take 300-400 consecutive uninterrupted images with an exposure time of 30 sec each. Combined with about 5 sec of readout/downlink time, this translates to a time coverage of 3-4.5 h per field. Since our site is near sea level, the typical seeing is quite poor at 3-5". The faintest objects recorded in

Corresponding author: Aleks Scholz
as110@st-andrews.ac.uk

[1] Our survey is named after Wilhelmina Fleming, an astronomer born in Dundee, 14 miles away from our telescope, in 1857 (as Wilhelmina Stevens). At age 21, she emigrated to Boston, and was hired by Edward Pickering, first as maid, then in 1881 as human "computer" in the analysis of spectra and images. Among many other achievements, Fleming discovered hundreds of variable stars. Fleming became curator of the astronomical photographs at Harvard in 1899 and a honorary member of the Royal Astronomical Society 1906. She died in Boston in 1911.

the images taken for this survey reach 17 mag in the Gaia G-band.

So far, we covered twelve fields between January 2019 and February 2020, before the pandemic forced us to close the observatory. These twelve fields are in two bands in galactic longitude, 135-142 deg and 196-199 deg. We built a pipeline for the data reduction that includes bias and flatfield correction, object detection in a master image, measuring offsets between master and all other images, aperture photometry for all objects in all images, differential calibration using bright, unsaturated stars in the field, and variable star detection. The last step was achieved by comparing the standard deviation in a given lightcurve to the median standard deviation of stars at a similar brightness. The pipeline uses tools within astropy (Astropy Collaboration et al. 2013, 2018). Finally, for all variable star candidates, the lightcurves and a thumbnail of the master image around the candidate were examined visually. All code and published outputs of the survey are stored in a public repository.[2]

3. VARIABLE STARS

In the twelve fields observed so far, we found eight variables with obvious structure in the lightcurves not seen in control objects, as shown in Fig. 1. Seven of them have variations well approximated by a sinewave, in five cases with a period < 5 h, two with longer periods. The final variable, #4, possibly shows multiple periods. The amplitudes of the sinewaves correspond to flux variations ranging from 10 to 50%. All have an entry in Gaia DR2, with distances ranging between 0.5 and 7 kpc. Their Gaia DR2 G-band magnitudes range from 12.8 to 16.5 (Gaia Collaboration et al. 2018).

Star #2 is known as V1004 Per in the General Catalogue of Variable Stars (Samus' et al. 2017), listed as δ Scuti variable with a period of 1.4 h. With our lightcurve we measure a period of 1.44 h. Examining the colours in Gaia, 2MASS, and WISE, the star is suspiciously red for this type of variable and needs spectroscopy for confirmation.

As mentioned, the lightcurve of star #4 shows multiple modes and is not fit by a single period. This in combination with the rapid variability strongly suggests it is also a pulsating δ Scuti star. According to its Gaia photometry, the star is clearly located in the colour-magnitude space populated by δ Scuti variables (Gaia Collaboration et al. 2019).

Out of the eight variable stars, five are included in the ASAS-SN Catalogue of Variable Stars (Shappee et al. 2014; Jayasinghe et al. 2021). The three stars not in the ASAS-SN database are the aforementioned #2 and #4, as well as #6. To our knowledge, star #6 is a new variable star discovered first in our survey.

Of the five that are listed in ASAS-SN, the period reported by ASAS-SN is significantly longer than the one that is apparent from our lightcurves. In three cases the ASAS-SN period is overestimated by a factor of two, for the other two it is about a factor of 5-6. ASAS-SN classifies all five as eclipsing binaries (three as WUMa-type, two as Algol-type). Based on our lightcurves and their position in the colour-magnitude space, this may be a plausible classification.

4. CONCLUDING REMARKS

The comparison with GCVS and ASAS-SN highlights that high-cadence surveys with limited depth are useful additions to ongoing and future monitoring programs. Surveys such as the Fleming can help to reliably determine the nature and periods of stars varying on short timescales. In addition, such surveys can discover new variable stars (such as #6) with no prior classification in the literature. In the future we expect that the Fleming Survey will be strongly complementary to the catalogues of variable stars produced by Gaia and the Vera Rubin Telescope. Scaling from the observed fields to the planned full survey coverage, we expect that we will produce a library of high-cadence lighcurve for several thousand bright variable stars with short-period lightcurves.

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REFERENCES

Astropy Collaboration, Robitaille, T. P., Tollerud, E. J., et al. 2013, A&A, 558, A33

Astropy Collaboration, Price-Whelan, A. M., Sipőcz, B. M., et al. 2018, AJ, 156, 123

Dame, K., Belardi, C., Kilic, M., et al. 2019, MNRAS, 490, 1066

Gaia Collaboration, Brown, A. G. A., Vallenari, A., et al. 2018, A&A, 616, A1

[2] https://github.com/aleksthethird/Fleming

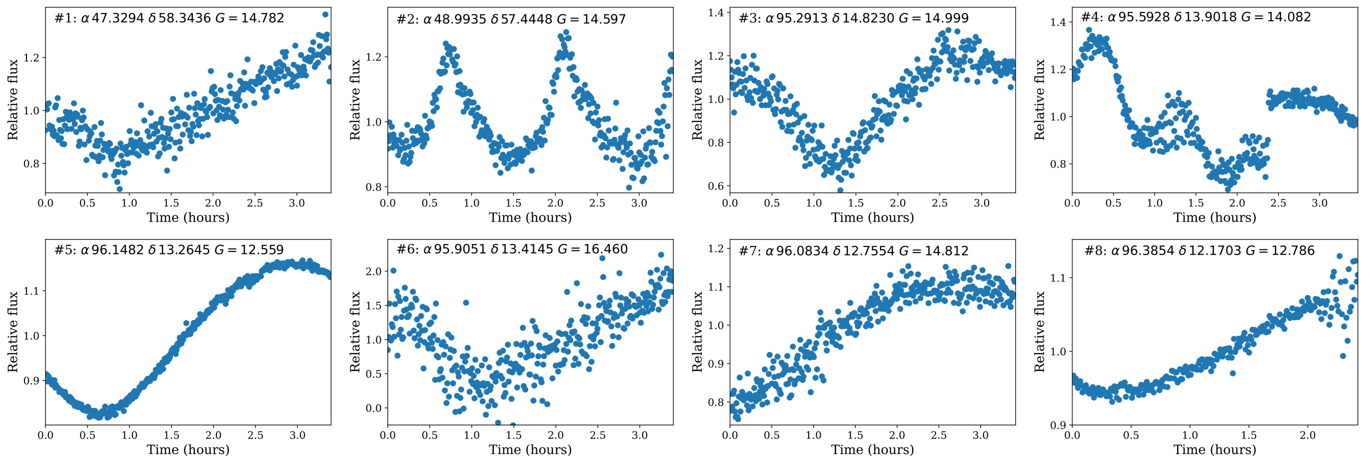

Figure 1. Lightcurves of the eight periodic variable stars detected by the Fleming Survey, observed here for the first time with high cadence. Right ascension and declination are given in degrees. The identifier referred to in the text and the Gaia G-band magnitude are also included.

Gaia Collaboration, Eyer, L., Rimoldini, L., et al. 2019, A&A, 623, A110

Jayasinghe, T., Kochanek, C. S., Stanek, K. Z., et al. 2021, MNRAS, 503, 200

Kupfer, T., Prince, T. A., van Roestel, J., et al. 2021, MNRAS, 505, 1254

Macfarlane, S. A., Toma, R., Ramsay, G., et al. 2015, MNRAS, 454, 507

Samus', N. N., Kazarovets, E. V., Durlevich, O. V., et al. 2017, Astronomy Reports, 61, 80

Shappee, B. J., Prieto, J. L., Grupe, D., et al. 2014, ApJ, 788, 48

Toma, R., Ramsay, G., Macfarlane, S., et al. 2016, MNRAS, 463, 1099