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Wide-Field Variability Surveys: A 21st Century Perspective

Variable stars in the northern Galactic plane from KISOGP

Noriyuki Matsunaga[1,⋆] on behalf of KISOGP team

[1] *Department of Astronomy, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*

Abstract. We have conducted a large-scale survey of the northern plane using Kiso Wide Field Camera attached to Schmidt telescope at Kiso Observatory. The KISOGP (KWFC Intensive Survey of the Galactic Plane) project has made 40–70 epoch observations in *I* band of about 320 square degrees for 5 years starting in 2012. The limiting magnitude is around 16.5 in *I*. In the data analysis so far, we detected a couple of thousands of variable stars including approximately 100 Cepheids and more than 700 Miras. Roughly 90% of them were not previously reported as variable stars, indicating that there are still many relatively bright variables to be found in the Galactic plane.

A large fraction of stars and gas is concentrated within the Galactic disk. In fact, approximately half of the baryonic mass within our Galaxy, $\sim 4 \times 10^{10}\ M_{\odot}$, is found in the disk ([1]). The stellar populations in a large space of the disk have, however, remained elusive due to the interstellar extinction. Historic surveys of variable stars, mostly done in the optical wavelengths, were far from complete (see, e.g., Fig. 1 in [2]). *Gaia* and other ongoing surveys in the optical are expected to find many new variables, while infrared surveys would be more effective for objects obscured in the disk (see our review [3] in these proceedings). We have conducted an *I*-band survey of variable stars in the northern Galactic disk because it has been less explored compared to the southern part for which OGLE[1] and VVV[2] have discovered a large number of new variables.

The instrument used for our survey is Kiso Wide Field Camera (KWFC) attached to 105-cm Schmidt telescope in Kiso Observatory, Japan ([4]). This camera has been designed for wide-field observations by taking the advantage of a large focal-plane area of the Schmidt telescope. Eight CCD chips with a total of 64 Mpixels cover a field-of-view of $2.2^{\circ} \times 2.2^{\circ}$. The distortion is negligible (at least smaller than $0.3''$) across the entire 4.8 deg^2 field. The survey is named KWFC Intensive Survey of the Galactic Plane (KISOGP) and has been conducted for 5 years starting in 2012. The main goal is to study the Galactic structure using pulsating stars as tracers and we have been also conducting follow-up observations of variable stars we find in both photometric and spectroscopic ways.

Our survey region is composed of 80 KWFC fields-of-view covering $\sim$ 320 deg^2 between 60 and 210 degrees in Galactic longitude (Fig. 1). The photometric observations are only in *I* band and cover the magnitude range of 9.5 to 16.5 magnitude in *I* with signal-to-noise ratio better than 30. For each epoch per each field, an exposure with 5 sec and three exposures with 60 sec are combined. The numbers of epochs for the 5-yr time monitoring ranges from 50 to more than 100, of which 40- or more-epoch datasets are confirmed to be of useful quality.

⋆ matsunaga@astron.s.u-tokyo.ac.jp

[1] http://ogle.astrouw.edue.pl

[2] https://vvvsurvey.org

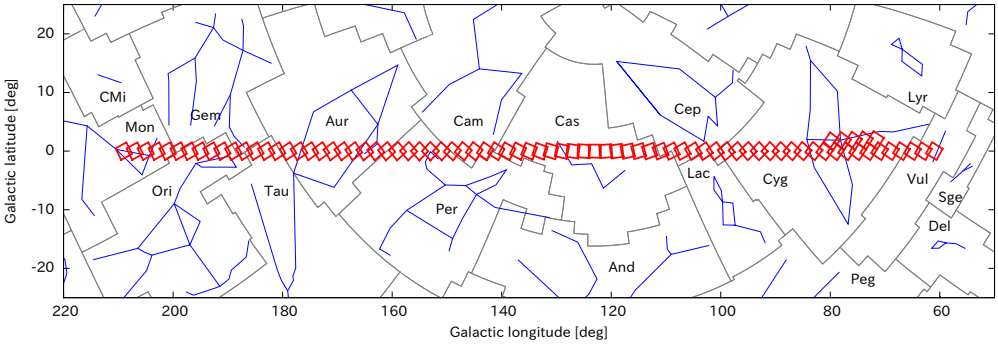

Figure 1. KISOGP survey region.

In our entire survey field, we have detected more than 5 million objects, of which about 50,000 variable star candidates are found, and data analysis is still in progress. So far we have searched for periodic variable stars with relatively large amplitudes and identified ∼100 Cepheids and more than 700 Miras. Roughly 90% of them were not reported as variables before. Preliminary estimates of their distances using the period-luminosity relations and 2MASS JHK_s magnitudes indicate that they are scattered across a large space of the northern Galactic disk, from a couple of kpc to more than 10 kpc from the Sun. Their distribution of Galactocentric distances covers ∼8 to 15 kpc. They will be important tracers of the outer disk. There are also RR Lyrs, a large number of eclipsing binaries ($>$ 1000), and other types of variables. While we are trying to finalize the data analysis for these variables, there are many other variables with smaller amplitudes and/or irregular variations.

In order to take advantage of the newly found Cepheids and Miras, we have been conducting several follow-up observing programs. For Cepheids, we have used the Subaru telescope to take high-resolution spectra and several telescopes including Las Cumbres Observatory's global network[3] to collect multi-color photometric data. For Miras, we have collected hundreds of low-resolution spectra to classify them into oxygen-rich and carbon-rich using the 188-cm telescope at Okayama Astrophysical Observatory[4], NAOJ, and the 2-m Nayuta telescope at Nishi-Harima Astronomical Observatory[5].

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[4] http://www.oao.nao.ac.jp/en/
[5] http://www.nhao.jp/en/