P15

Galactic Plane Survey Plan with ULTIMATE-Subaru

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Abstract

We are planning to conduct a very wide-field survey (approximately 60 square degrees, l=20-50 degrees and |b|< 1 degree) of the Galactic Plane (GP) using the ULTIMATE-Subaru Wide Field Imager (WFI). This survey will utilize a variety of narrow, medium, and broad-band filters to uncover obscured objects along the GP, including asymptotic giant branch stars (AGBs), cataclysmic variables (CVs), and supernova remnants (SNRs). CN/H_2O, H_2O, and CO filters diagnose the spectral types of stars (e.g., C-rich vs. O-rich; early type vs. late type). The spatial distribution of C-rich and O-rich AGBs revealed by the diagnosis allows us to investigate the conditions under which AGBs become C-rich or O-rich. The spectral types of OH/IR stars including non-variable objects (late- or post-AGBs) gives their evolutionary status and reveal the relationship between stellar evolution and mass-loss activity. Employing [FeII], H_2, and Paβ narrowband imaging (with high angular resolution) along the GP will allow us to map the shocked interstellar medium in SNRs. Additionally, the Paβ and Brγ narrow-band filter survey will help trace faint CVs along the GP, which are part of the Galactic Diffuse X-ray emission. In this poster, we present the detailed plan for our GP survey.

1. Overview

The evolution of our galaxy and individual celestial objects is a fundamental topic in astronomy. In order to understand them, many surveys have been conducted to study the structure and population of our galaxy. However, there are still many regions and objects unseen by previous observations: dust-obscured regions and dusty objects. They could be important probes for elucidating unresolved issues such as the inner structure of our galaxy, the history of star formation, the evolution of late-evolving stars, and the origin of diffuse X-ray emission in the interstellar regions. Near-infrared (NIR) surveys of the Galactic Plane (GP) are effective for studying such dusty regions and sources. However, since the GP is very crowded, the observational sensitivity is limited by confusion, and high spatial resolution is required to make deep surveys. For this reason, the ULTIMATE/WFI, with its high spatial resolution using GLAO (~0.2″ @ K-band) and wide field of view (14′×14′), is arguably the most powerful instrument for NIR GP surveys. Here, we describe our proposed survey and the science cases that can be realized through it.

2. Observation Plan

Survey Region and Filters

- In our survey, a part of the GP at l **= 20–50 deg and |b| < 1 deg (60 deg²)** is surveyed with various band-pass filters with sensitivities deeper than previous GP surveys.
- The filter set we are planning consists of 11 filters (Table 1)
  - three **wide-band filters** (J, H, and K)
  - three **medium-band filters** (CO, H_2O, and CN/H_2O)
  - three **narrow-band filters** (Paβ, Brγ, and [FeII]), and two **dual narrow-band filters** (Paβ-continuum and Brγ-continuum; see also Fig. 1) which measure the continuum level to detect sources which have small equivalent width of emission feature of Paβ/Brγ.
- These filters allow us to determine the spectral type of individual objects and to discover unseen obscured objects such as evolved stars, cataclysmic variables (CVs), and supernova remnants (SNR).

Table 1: Properties of ULTIMATE-WFI filters proposed for the Galactic Plane survey.

Filters	Center Wavelength (μm)	Bandwidth (μm)
J	1.24	0.16
H	1.66	0.25
Ks	2.16	0.26
CN/H_2O	1.45	0.10
H_2O	2.05	0.10
CO	2.40	0.10
Paβ	1.281	0.02
Paβ-continuum	1.281	0.02×2 bands
[FeII]	1.257	0.02
Brγ	2.165	0.02
Brγ-continum	2.165	0.02×2 bands

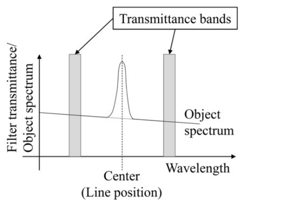

Figure 1 : Schematic view of a dual narrow-band filter used to measure the continuum level. The filter has two transmittance bands at the wavelengths shorter and longer than the target line position. This kind of filter allows us to precisely determine the continuum level for the line even for highly reddened objects.

Estimated exposure time and the limiting magnitude

- Achievement sensitivity: to complete the proposed 60 deg², multi-filter imaging survey (with 11 filters) down to ~20 AB mag.
- We estimated the required exposure time based on the J/H/K-band sensitivity of the ULTIMATE/WFI (J: 24.1 AB mag; H: 23.8 AB mag; K: 24.1 AB mag @ 10min-5σ-10min, realistic/good seeing condition).
- For the narrow- and medium-band filters, we estimated the sensitivity by scaling with the observation bandwidths, and calculated the exposure time by using the estimated sensitivity.
- As a result, the total exposure time in one field is estimated to be 660 seconds (5σ, 4 dith) including overheads, and the total observing time is **38 nights.**

3. Targets

Our galaxy is a barred spiral galaxy with spiral arms. Star formation is actively taking place, and stars of various types and ages exist in the spiral arm. To reveal the formation and evolution of our galaxy, we plan to search the distribution of various targets.

Stellar classification & distribution census in our Galaxy

- Since the equivalent widths are not much affected by reddening due to interstellar dust, it is possible to distinguish between high-temperature stars with strong reddening and intrinsically red low-temperature stars.
- We focus on CO absorption band (indicator of the temperature of stars), H_2O (classify giants/dwarf), CN absorption band (feature of carbon stars).
- We classify C-rich, O-rich stars using the diagram of CN/H_2O versus CO, H_2O versus CO, and CN/H_2O versus H_2O using medium-band and narrow-band filter surveys (Fig. 2).

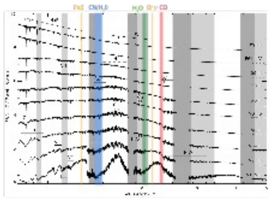

Figure 2 : NIR spectra of giant stars (Rayner et al., 2009) and the transmission of MB and NB filters which use in this study.

Finding & monitoring OH/IR stars

- OH/IR stars with and without significant periodic variability are considered to be in the late asymptotic giant branch (AGB) and early post-AGB phases, respectively.
- The stellar evolution, especially between these two phases, is poorly understood due to the heavy circumstellar extinction.

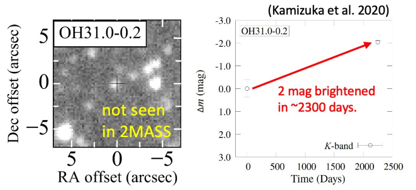

Figure 3 : Unexpected brightening of a non-variable OH/IR star (OH31.0–0.2) found in the UKIDSS-GPS survey.

But recently, deep NIR surveys have found unexpected brightening of non-variable OH/IR stars that may be related to stellar evolution (Fig. 3).

- The deeper NIR survey will discover unseen NIR counterparts of non-variable OH/IR stars, and the spectral diagnosis will reveal their evolutionary status. Monitoring, if realized, would provide new data of their temporal evolution and shed light on their transitional evolution.

Search for faint Cataclysmic Variables using NB filter survey

- Galactic Diffuse X-ray Emission (GDXE), which is an X-ray emission extends along the GP, is considered to consist from faint X-ray sources such as CVs and active binaries.
- However, since these results are based on X-ray data alone, in which photon statistics are generally too poor to constrain the nature of individual sources.
- NB (Paβ and/or Brγ) filter survey for searching faint obscured CVs (Fig. 4).
- Since CVs have large continuum component, we use dual NB-continuum-filters (Fig.1) to obtain and extract continuum component to detect faint CVs and reveal the nature of the GDXE.

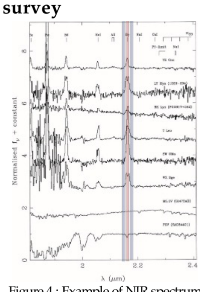

Figure 4 : Example of NIR spectrum of CVs (Dhillon et al., 2000) and the transmission of Brγ (light red) and Brγ-continum filters (light blue).

Narrow-band filter survey of supernova remnants

- There are many SNRs in the GP, where the supernova shock waves interact with the interstellar medium (e.g. Green et al., 14).
- The [FeII] line can effectively trace the shocked interstellar medium in SNRs (Fig. 5).
- We will observe SNRs along the GP in the [Fe II] and Paβ line emissions with the wide-field ULTIMATE/WFI. We aim to study dust destruction in SNRs using the [Fe II]/Paβ ratio, which gets higher in strong shock regions (e.g. Koo et al., 2014).

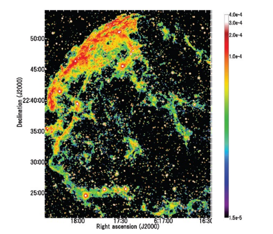

Figure 5 : [Fe II] 1.257 μm line map of the Galactic SNR IC443 (Kokusho et al., 2013). The color levels are given in units of erg s⁻¹ cm⁻² sr⁻¹

4. Summary

- We plan the wide-field GP survey (l = 20–50 deg and |b| < 1 deg , 60 deg²) with ULTIMATE/WFI using various medium-band/narrow-band filters.
- To reveal the structure of our Galaxy and hidden stellar evolution, we consider various science such as stellar classification using medium/narrow-band filters, finding and monitoring OH/IR starts, searching faint CVs using NB filters, and observing SNRs with NB ([FeII] and Paβ) filters to study dust destruction in SNRs.