Multi-Color Near-Infrared Monitoring of Ultracool Dwarfs

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Our goal

Our goal is to reveal two topics about modulations of ultracool dwarfs.
1. Characterizing the modulations caused by the atmospheric variability
2. Searching for the eclipsing modulations of planets around ultracool dwarfs
Many authors have reported the photometric modulations of ultracool dwarfs probably caused by their rotation and atmospheric variability (e.g. Koen+2004;2005;Artigau+2009). Moreover, the monitoring observations which aim to reveal earth size companions around ultracool dwarfs have started (Blake et al. 2008).

http://www.z.phys.nagoya-u.ac.jp/~irsf/telescop/

Method

• Observation – the position locking by the continuous feedback -

We have used 1.4-m IRSF telescope at Sutherland, SAAO (South Africa Astronomical Observatory).
The camera is SIRIUS whose FOV is 7'x7' and pixel scale is 0.45 arcsec/pix, and we can simultaneously obtain 3 infrared color images (JHKs).
To achieve high precision for the monitoring observation, it is important to lock the target position on the image.
But IRSF has no auto guider. Then, we have developed the system to lock stellar images at same position.
The flow chart of this system is

| The initial position of the target on the image | → | Start tracking and exposure | → | Check and calculate the shift amount of the target | → | Feedback the info to the telescope and pointing |

After the development, we achieve to keep the shift amount below a few pixel. We can reduce the affection from bad pixel and the uncertainty of flat field.
This table show the summary of observations. In this time, we focused on bright targets. These sources are selected from DwarfArchieve.org.

Date	Exp time (sec)	The number of targets	Obs span (min)	Magnitude	SpT	Clear rate %
2011 Oct 11-20	30, 40	6	40-60	11-14@J-band	L0-L3	38

• Reduction/Analysis

We have used below tools for this study
• SIRIUS09
  ➢ A reduction pipeline tool for IRSF/SIRIUS data (provided by Y. Nakajima)
 ➢ The features are flat field correction, dark subtraction, and sky slope correction (reset anomaly)
• APPHOT
  ➢ A useful tool to conduct photometry for the data set of monitoring observation (e.g. transit, variable stars) (provided by A. Fukui)
  ➢ The features are photometry for a huge number of images at once and plotting the light curve

Preliminary results

We demonstrate one of our preliminary results. The figures show JHKs light curves after 30sec x 5 binning and subtracting the trend correlated with airmass and XY pixel shift.

— before subtracting the trend (photon noise)   — after subtracting the trend (photon noise + red noise)
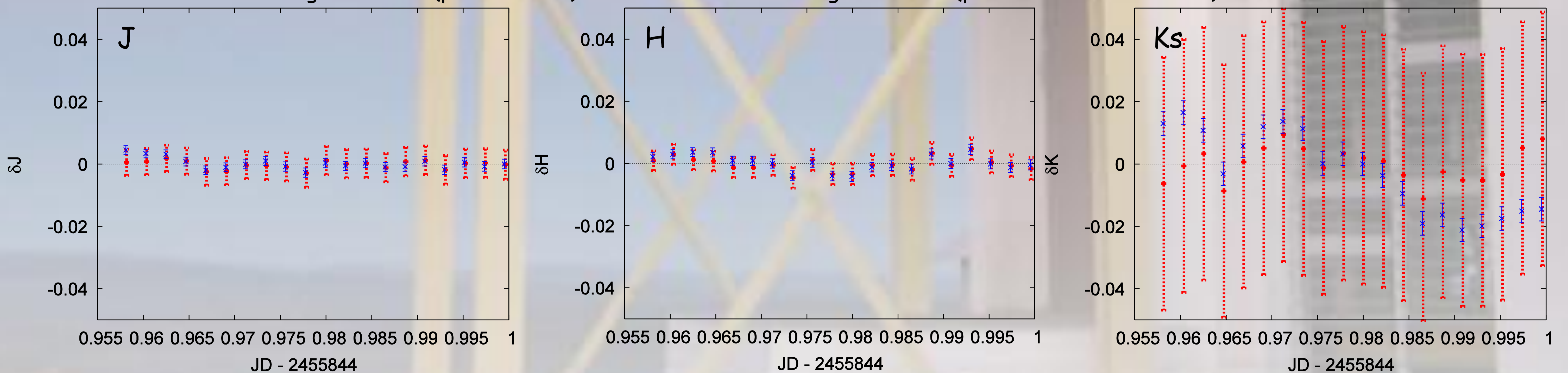
J~11.7mag, err~1.5mmag / 4mmag   H~11.1mag, err~1.5mmag / 4mmag   Ks~10.6mag, err~ 4mmag / 40mmag

Ks light curve after the trend subtracting has large error due to short time baseline or, probably intrinsic modulation. The next step are to confirm reproducibility and observe for longer periods.
Finally, we can obtain simultaneous JHKs light curves with high precision. It permits the detail investigation for the small amplitude modulation (<10mmag) caused by the surface variability of ultracool dwarf. And then, the below equation,

$$\frac{\Delta F}{F} \approx 0.008 \left(\frac{M_p}{M} \right)^{0.54}$$

1 M_{earth} results in a depth of 8 mmag
10 M_{earth} results in a depth of 30mmag (Blake et al. 2008)

shows that the transit event with a few earth mass companion around ultracool dwarf is detectable.

Summary

We have developed the system which locks the target position on the image for the high precision monitoring by using IRSF/SIRIUS. In the result, we have obtained multi-color light curve of ultracool dwarf with good precision (< 5mmag). To use this system, we can reveal the nature of the ultracool dwarf atmosphere and the earth mass companions around ultracool dwarfs.