JHKs Simultaneous Transit Photometry of GJ1214b

Norio Narita[1], Takuya Suenaga[1,2], Akihiko Fukui[3], Takahiro Nagayama[4], Yasushi Nakajima[1], Shogo Nishiyama[1], Motohide Tamura[1]

(1: National Astronomical Observatory of Japan, 2: Graduate University for Advanced Studies, 3: Okayama Astrophysical Observatory, 4: Nagoya University)

☆ Overview of GJ1214b ☆

GJ1214b is a transiting extrasolar planet orbiting around a cool red dwarf discovered by Charbonneau et al. (2009). The host star GJ1214 is an M4.5 type star with an estimated temperature of ~3000K lying 13 pc (42 light year) away from the Solar System. The planet GJ1214b has a mass of ~6.55 Earth mass and ~2.68 Earth radius. GJ1214b was indeed the first transiting super-Earth, discovered around a nearby M dwarf (see Fig.1).

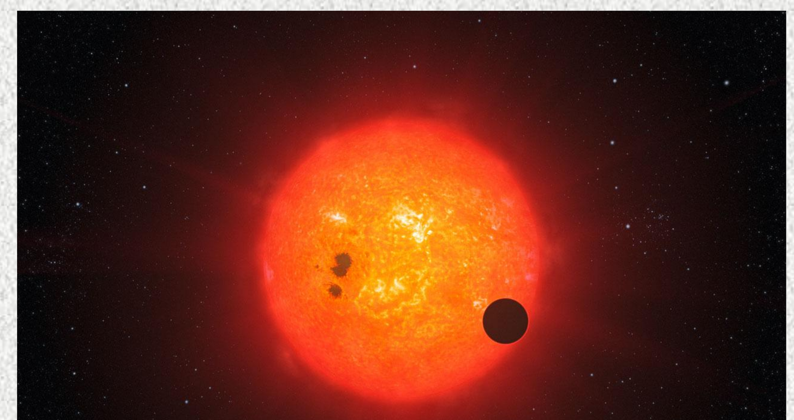

Fig.1: Artist's impression of GJ1214b (Credit: ESO/L. Calcada)

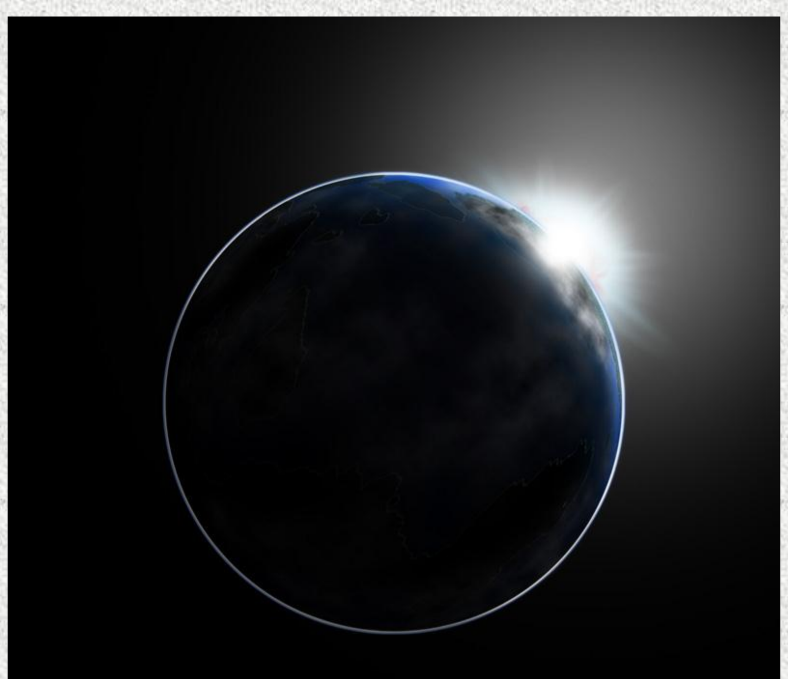

Fig.2: Illustration for transmitted lights through the planetary atmosphere (Credit: NAOJ)

☆ Merit of Transiting Planets to Study Planetary Atmospheres ☆

The unique configuration of transiting planets allows us to look into planetary atmospheres. Since a part of host star's lights have transmitted through atmosphere of a transiting planet (see Fig.2), depths of light extinction due to a planetary transit depend on wavelength, reflecting compositions and conditions of planetary atmospheres (e.g., high clouds or haze). Therefore multiband photometry and/or spectro-photometry are useful to characterize atmospheres of transiting planets.

☆ Introduction of IRSF/SIRIUS ☆

IRSF (InfraRed Survey Facility) is 1.4m telescope (see Fig.3) located in South African Astronomical Observatory (SAAO), Sutherland, South Africa. IRSF equips SIRIUS (Simultaneous 3color InfraRed Imager for Unbiased Survey) camera, which utilizes 2 dichroic filters and can observe 3 color (e.g., JHKs bands, see Fig.4) in near infrared wavelength simultaneously.

Fig.3: IRSF telescope. SIRIUS is installed at the Cassegrain focus. (Photo by Takuya Suenaga)

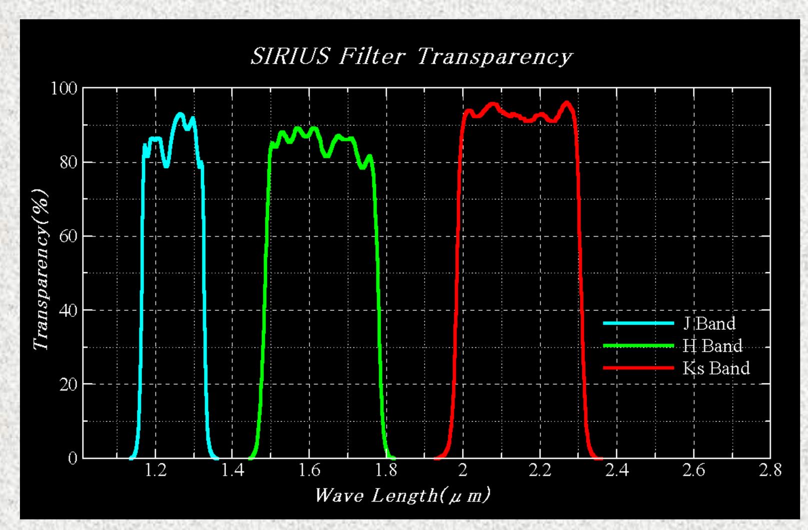

Fig.4: Transparency of SIRIUS broadband filters. Narrow band filters are also available.

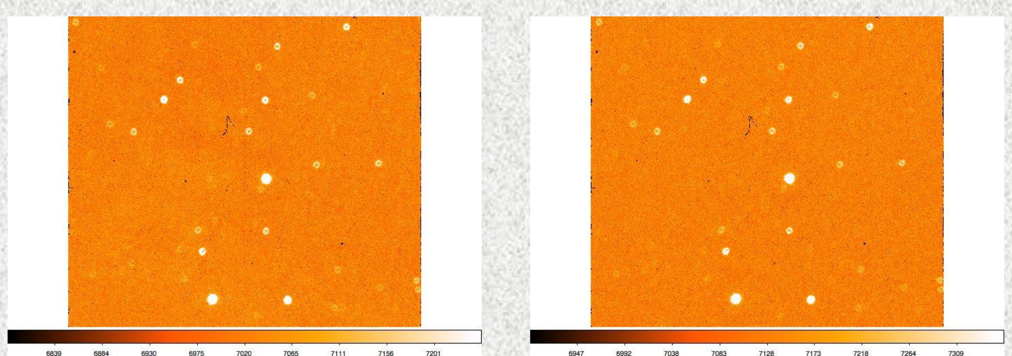

Fig.5: Ks band detector images at the beginning (left) and end (right) of observations for GJ1214.

☆ Position Locking Software ☆

To achieve high photometric precision, it is very important to lock stellar positions on detectors so as to avoid systematic errors due to the incompleteness of flat fielding for infrared detector arrays. Since IRSF does not equip an auto guider, we have developed a position locking software, which gives feedback to the telescope when the centroid of the target image shifts over a few pixels. The software worked well and target positions on 3 detectors were limited within a few pixels over a few hours. Fig.5 shows Ks band detector images at the beginning and end of observations.

☆ Observation and Analysis ☆

We observed a full transit of GJ1214b on August 14, 2011 (UT) covering ~3 hr. The exposure time was 49 s and the readout time was 16 s throughout the observation. The data were processed by a standard procedure of aperture photometry. The fluxes of GJ1214b were divided by the total fluxes of bright comparison stars. The flux ratios were then corrected to remove dependence on time (t), airmass (z), shifts of centroid on the detectors (dx, dy) as follows.

$f_{correct} = f_{original} \cdot k_0 \cdot 10\text{^}(k_t t + k_z z + k_x dx + k_y dy)$; k_0, k_t, k_z, k_x, k_y: free parameters

☆ Our Preliminary Results and Comparison with Previous Results ☆

Fig.6 and Fig.7 show light curves of GJ1214 before and after the correction above, with the best-fit curves for the corrected data. The photometric precisions (rms of residuals) are 1.95 mmag (J band), 2.01 mmag (H band), and 2.20 mmag (Ks band) respectively. The preliminary results for Rp/Rs (the ratio of the star and planet radii) are 0.1177±0.0014 (J band), 0.1174±0.0013 (H band), and 0.1152±0.0020 (Ks band).

As GJ1214b is one of the most interesting targets, numbers of observers have reported transit depths of this planet in various wavelengths (e.g., Berta et al. 2011, Bean et al. 2010, 2011, Croll et al. 2011, Desert et al. 2011, de Mooji et al. 2011).

Our preliminary results support a flat transmission spectrum reported by other observers within the conservative errors (considering red noises) in each band. Also, our Ks band transit photometry does not agree with the deeper transit depth reported by Croll et al. (2011) by about 2 sigma.

We do not have clear explanations for the difference at this point, but some possibilities include systematic errors in our or Croll et al.'s results, unocculted stellar spots, time variability (climate change) of GJ1214b's atmosphere.

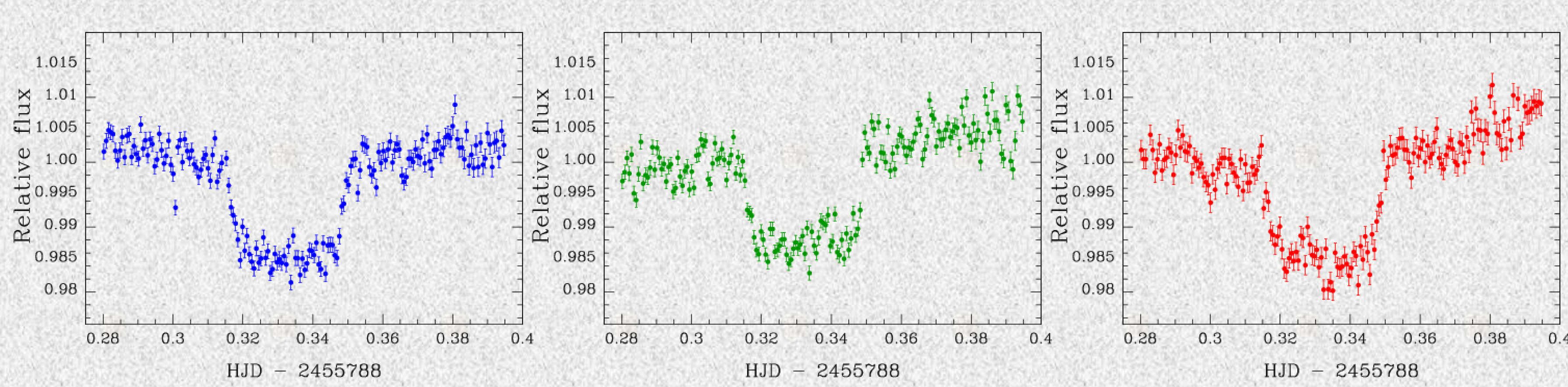

Fig.6: Raw light curves of GJ1214b for J band (left, blue), H band (middle, green), and Ks band (right, red). The errors are computed by photon noises.

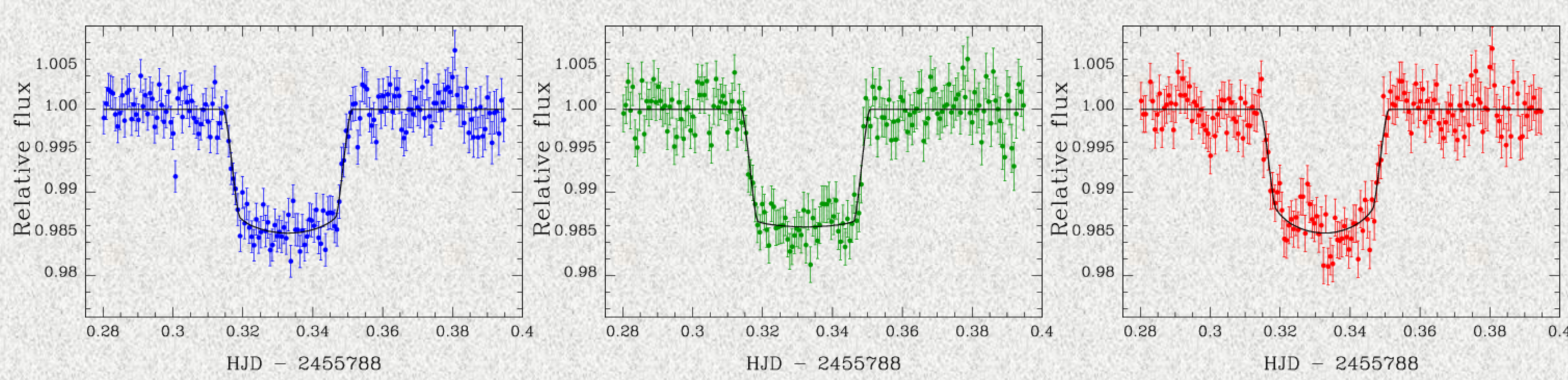

Fig.7: Same as Fig.6, but corrected light curves of GJ1214b. The errors are rescaled to match rms of residuals. Note that these are still preliminary.

☆ Summary ☆

We here presented JHKs simultaneous transit photometry of GJ1214b. We have demonstrated that IRSF/SIRIUS can achieve good precision (~2 mmag) for 3 bands in the near infrared region without an auto guider. It was the first test of transit photometry with IRSF/SIRIUS. Based on the results, we will utilize this facility for further transit photometry of interesting targets.