Subaru HDS Ground-based Transmission Spectroscopy for the Transiting Exoplanet HD189733b

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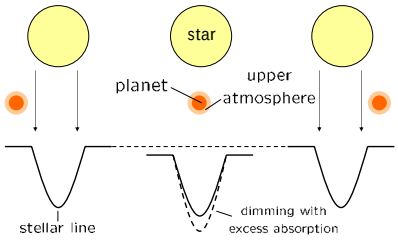
and the Subaru HDS collaboration team

Transmission Spectroscopy

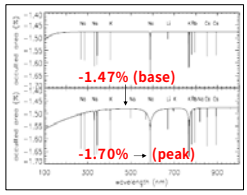
How to search for exoplanetary atmospheres?



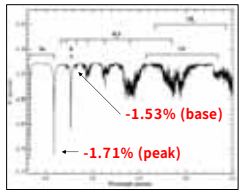
During planetary transits, a small fraction of stellar disk is blocked by the transiting planet and even smaller fraction of the starlight is transmitted through the optically thin portion of the planetary upper atmosphere.
Thus in transiting planetary systems, one can search for exoplanetary atmospheric components by comparing stellar spectra taken during transit and out of transit.
This methodology is referred to as "transmission spectroscopy."

Theoretical Studies

How much signal is theoretically predicted?



Seager & Sasselov (2000)

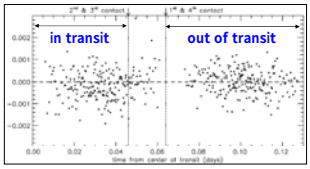


Brown (2001)

Theoretical transmission spectra for some planetary atmospheric models were calculated using radiative transfer codes. The above figures show results of such simulations for "cloudless atmosphere models."
Namely, the transmitted starlight was not blocked by clouds of the planet.
The theoretical simulations predict ~0.15% excess absorption around Na D lines (5890, 5896 Å) due to the planetary atmosphere.

Previous Results

HST (space-based) observation

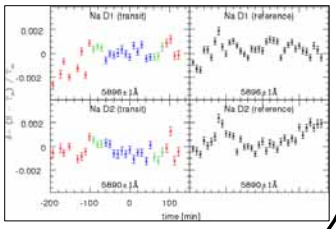


Charbonneau et al. (2002)

- 4 transits were observed
- Instrument: HST/STIS
- Spectral resolution: R ~ 5540
- Integral interval: 5887 ~ 5899 Å
- Difference of in and out of transit
  = -0.000232±0.000057 (Detection)

Subaru HDS Ground-based Observation

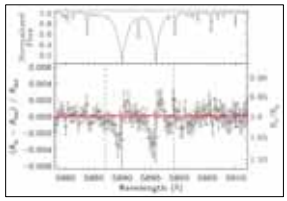
- 1 full-transit was observed
- Instrument: Subaru/HDS, Std-Yb
- Spectral resolution: R ~ 45000
- Integral interval: 2 Å around each Na line
- Difference of in and out of transit
  = +0.0004 ± 0.0010 (No detection)
- Systematic variations are remaining



Narita et al. (2005)

Recent Discoveries in 2008

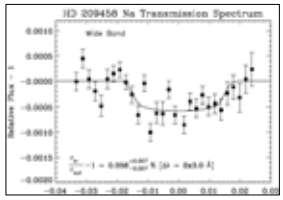
HET observation for HD189733



Redfield et al. (2008)

Recently, Redfield et al. reported the first ground-based detection of Na excess absorption in HD189733b. They observed HD189733 for 36 nights (11 transits) with the HET/HRS and found a difference of -0.000672±0.000207 (5887~5899 Å) between in and out of transit spectra.

Re-analysis of Subaru HD209458 data



Snellen et al. (2008)

On the other hand, Snellen et al. reported re-analysis of our Subaru HDS data for HD209458.
They found the systematic variations were caused by the CCD non-linearity, and reported a detection of -0.00056±0.00008 (2lines×3 Å) excess absorption around Na D lines.

Our Observation and Analysis Method

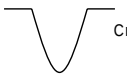
Observation

- Target: HD189733
- Date: July 13, 2007 (UT)
- Instrument: Subaru/HDS, Std-I2a
- Spectral resolution: R ~ 120000
- SNR per pixel: ~850 (in)
  (around Na D lines) ~1200 (out)

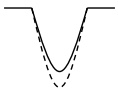
Applied Corrections

- Telluric (Earth's atmospheric) lines
- HDS CCD non-linearity
- Blaze function

Analysis Procedure



Step 1:
Create a template spectrum from all out-of-transit spectra.



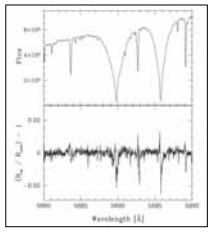
Step 2:
Calibrate the template spectrum so as to match its blaze function to each spectrum.

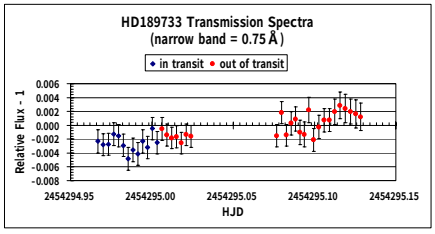
Step 3:
Calculate residual spectrum and integrate the residuals at specific atomic lines.

Our data have enough SNR to detect the signal reported by Redfield et al. !

Preliminary Results

Subaru Results for HD189733





The above figures show the same plots as Redfield et al. (2008) and Snellen et al. (2008) presented, using our new HD189733 data.
The preliminary results are consistent with the detection by Redfield et al. (2008), and systematic variations are significantly reduced by the correction for CCD non-linearity.
We plan to propose further observations with the Subaru HDS in order to search for weather variations in HD189733b and other bright transiting planetary systems!