Developing Spectrophotometer for Exoplanet Transmission Spectra

MYEONG-GU PARK (KYUNGPOOK NAT. U.)

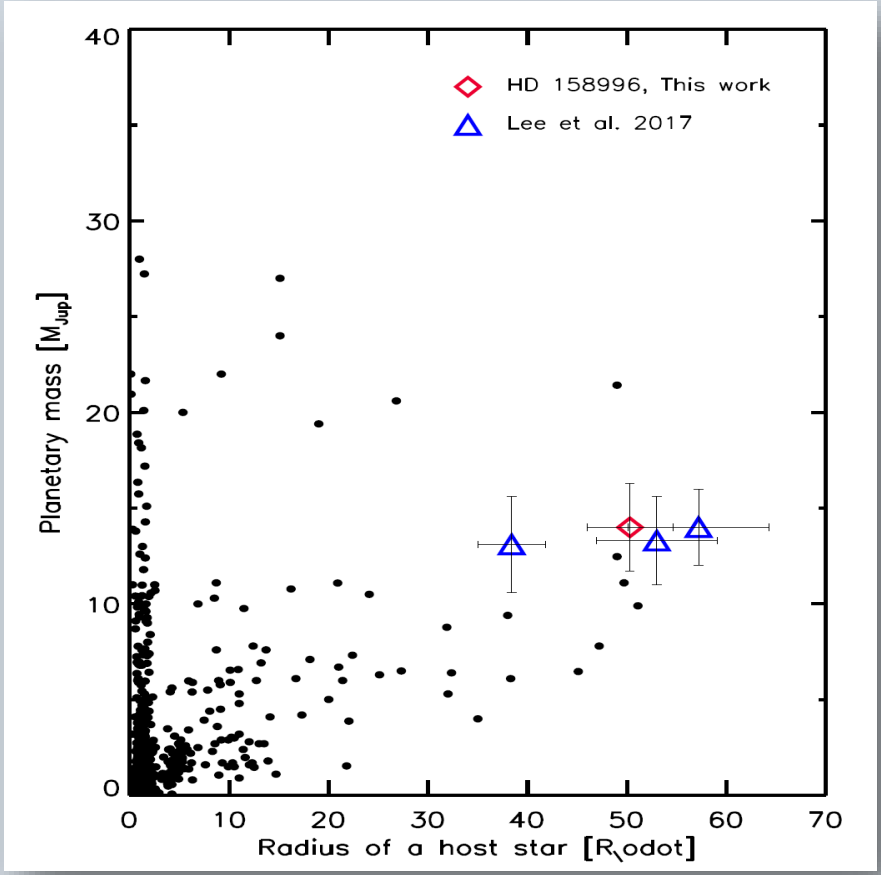
INWOO HAN, KANG-MIN KIM, BYEONG-CHEOL LEE (KASI),
TAE-YANG BANG, YEONHO CHOI (KNU)
G. VALYAVIN (SAO) ETC

Exoplanet studies with BOES

29 exoplanets so far

- Largest sample of giants with planets
- Largest stars with planets
- Evolved stars with planets

Stellar oscillations, rotations, surface activities



From discovery to the characterization of planets

Density: rocky or gaseous

- Radius – Transit observation
- Mass – RV observation

Exoplanet atmosphere

- Composition of exoplanet atmosphere
- Biomarker from earth-like planets within habitable zone
  - Key science of GMT+G-CLEF

Bright-enough targets from TESS

Transiting Exoplanet Survey Satellite (TESS)

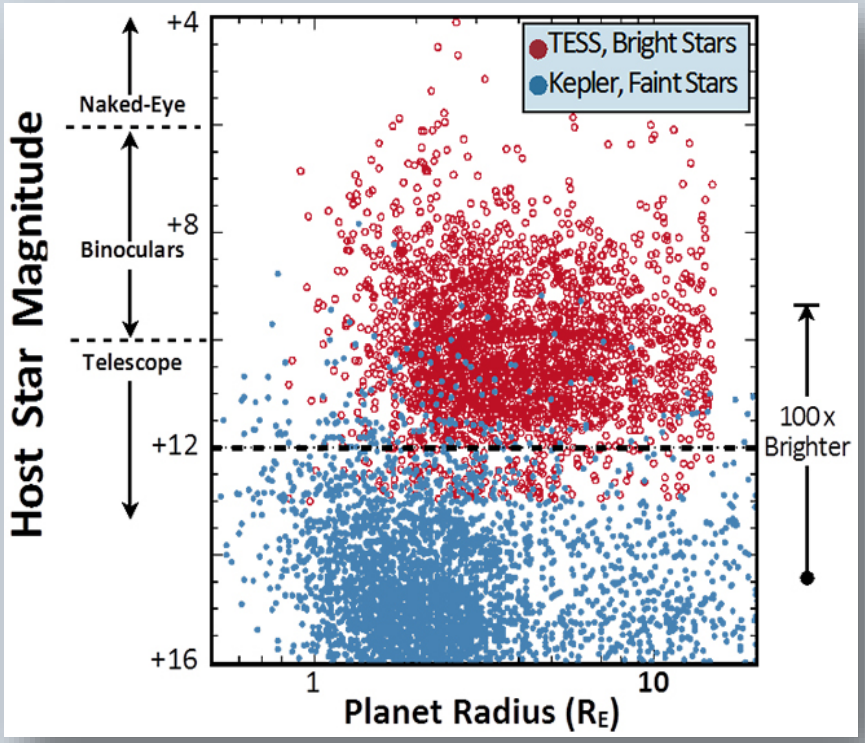
Launched April 2018
- 4 x 100 mm
- 24°x24°

2 yr survey

m < 12 mag
- 100 times brighter than Kepler sample

Expectations
- ~ 5,000 super-Earths
- ~ 1,600 from nearby bright stars
- ~ 50 Earths in HZ confirmed by RV follow-ups

Observable with 1 ~ 2 m telescopes



Follow-up observations on the TESS candidates

RV

- Confirmation and mass determination by RV observations.
- Telescope size
  - BOES: BOAO 1.8 m
  - HARPS: ESO 3.6 m
- RV precision
  - BOES: ~ 7 m/s
  - HIDES: ~ 3 m/s (being upgraded to 25% higher sensitivity)
  - HARPS: ~ 0.3 m/s

Photometry

- Confirmation and precise radius determination
- Possible with 1 – 2 m class telescopes

TEN-X collaboration

- KASI, NAOJ, MPE, NAOC, TITECH, SAO, KNU, CBNU, NYSC

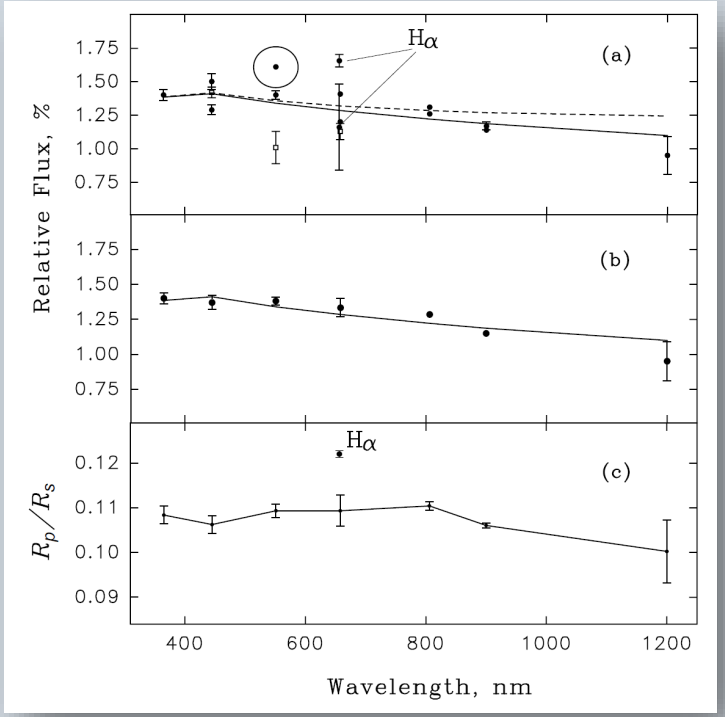
Oct. 2018

Transmission Spectroscopy

Spectroscopy of starlight through exoplanet atmosphere
- Comparison of spectra during and off the transit

HST + Spitzer (GMT)

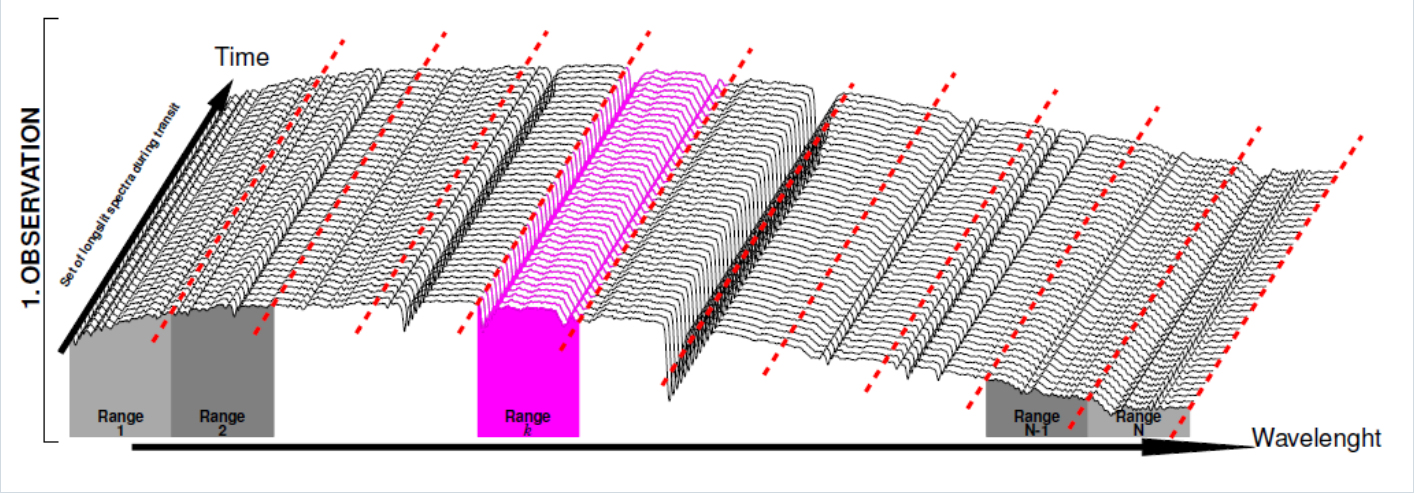
Multi-band photometry
- Transit strength in different band
- Exoplanet radius spectrum
- Problems
  - Simultaneous photometry not possible
  - Filter change time
  - Fixed bands



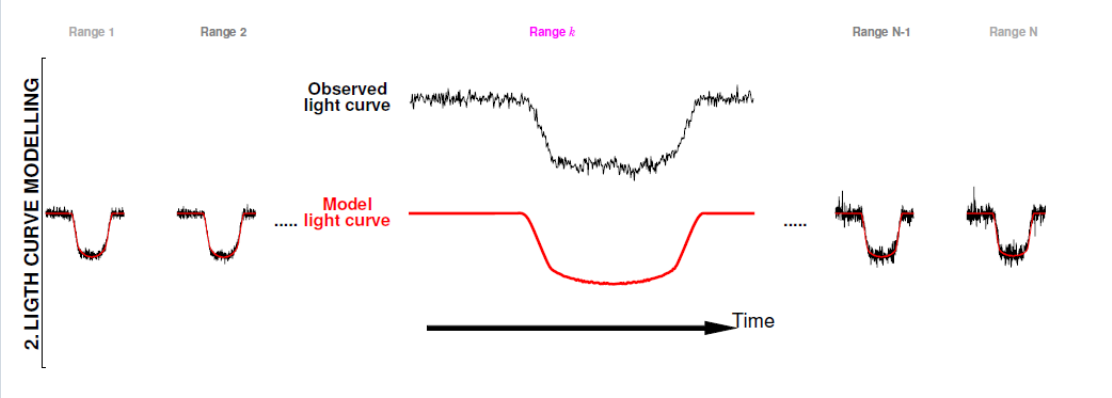
Valyavin+ 2018

Transmission Spectra with Spectrophotometer

1. Time series low dispersion spectral observation during the transit



2. Light curve from the photometry for each spectral band (~ 100 Å)

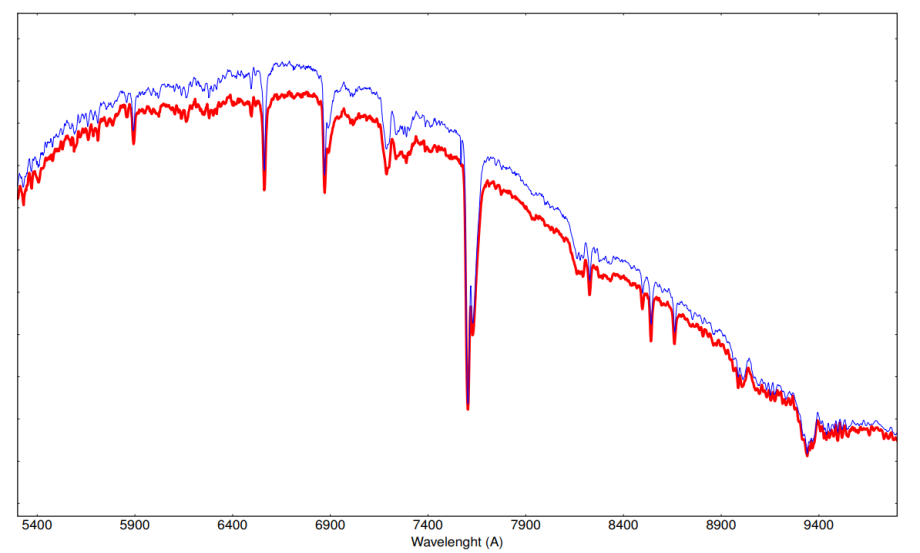


3. Planet radius determination at each spectral band by transit modeling

4. Characterization of planet atmosphere by comparison with exoplanet atmosphere model

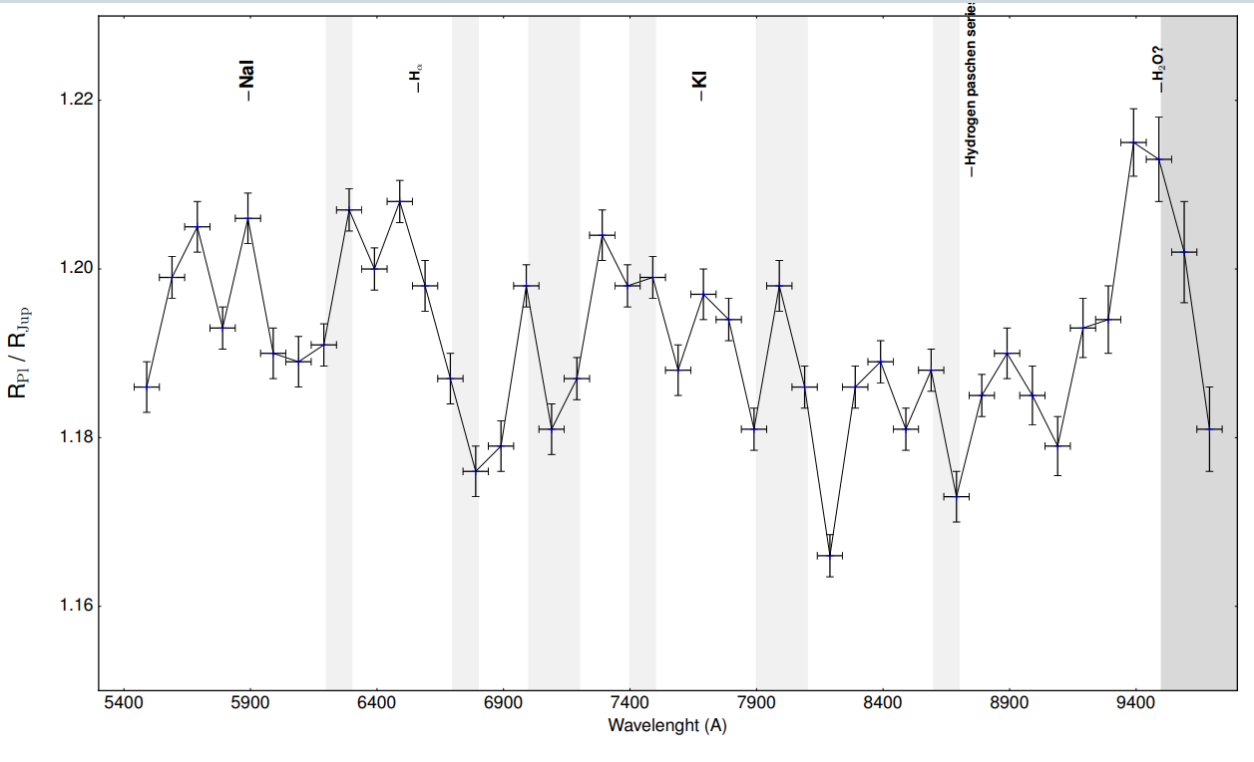
- Valyavin et al. (2018)

Spectra of WASP-32 (upper plot) and the reference star (lower plot)



GTC + OSIRIS spectrograph
20 Oct 2013. Grating R1000R resolution ~1000

- Radius spectrum of WASP-32b



Planet radius limit

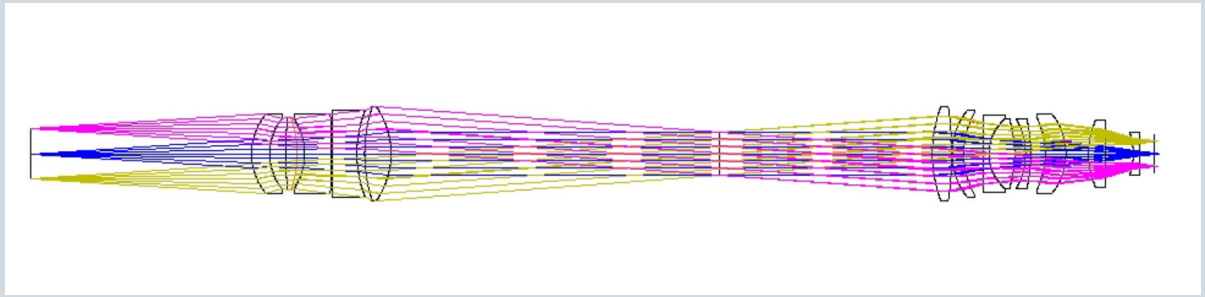
- 2 m class telescope
  - Down to 0.0016 R_J for 8 mag stars
  - Probe exosphere of Jupiter- and Saturn-size exoplanets
  - Hot super-Earth or Neptune

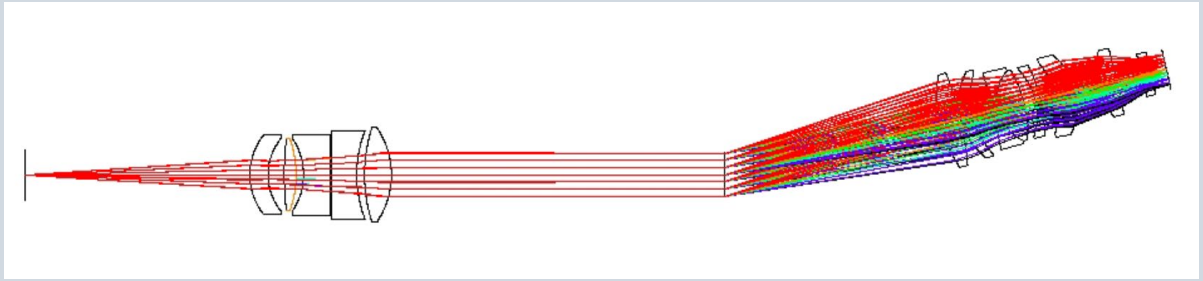
Photometric precision requirement

- Better than %
- Reference star
  - Simultaneous observation of a reference star to minimize the atmospheric effect
  - Reference star with similar magnitude and spectral type

LoSTaS (Low Resolution Spectrophotometer for Transmission Spectroscopy)

- 1.8 m, f/8
- Collimator
  - 5 OHARA lens
  - f = 320 mm
  - Beam diam. 30 mm
- Imaging camera
  - 8 OHARA lens
  - f = 160 mm
- Coverage
  - 4000 – 8000 Å
- FoV
  - 5 arcmin
- Spectral resolution
  - 250





Challenges

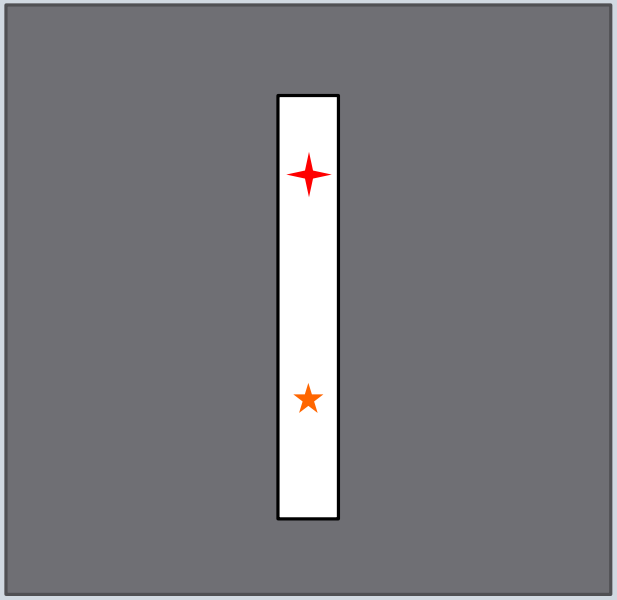
Spectrophotometer, not spectrometer

Absolute calibration

- Sky background
- Comparison(reference) star

Slit

- Simultaneous obs of two targets
- Wide FOV
- Large width
  - 20” ~ 30”



Reference stars

- Target stars
  - < 10 mag from TESS candidates
- Mag difference within 1.5 ~ 2 mag
- Best with similar spectral type
- Number of reference stars expected (Azamat)

Magnitude	10 x 10 arcmin
10.0	0.265
10.5	0.440
11.0	0.723
11.5	1.179
12.0	1.905