Probing Transiting Exoplanet Atmospheres with Gemini/GMOS

Credit: Gemini/AURA

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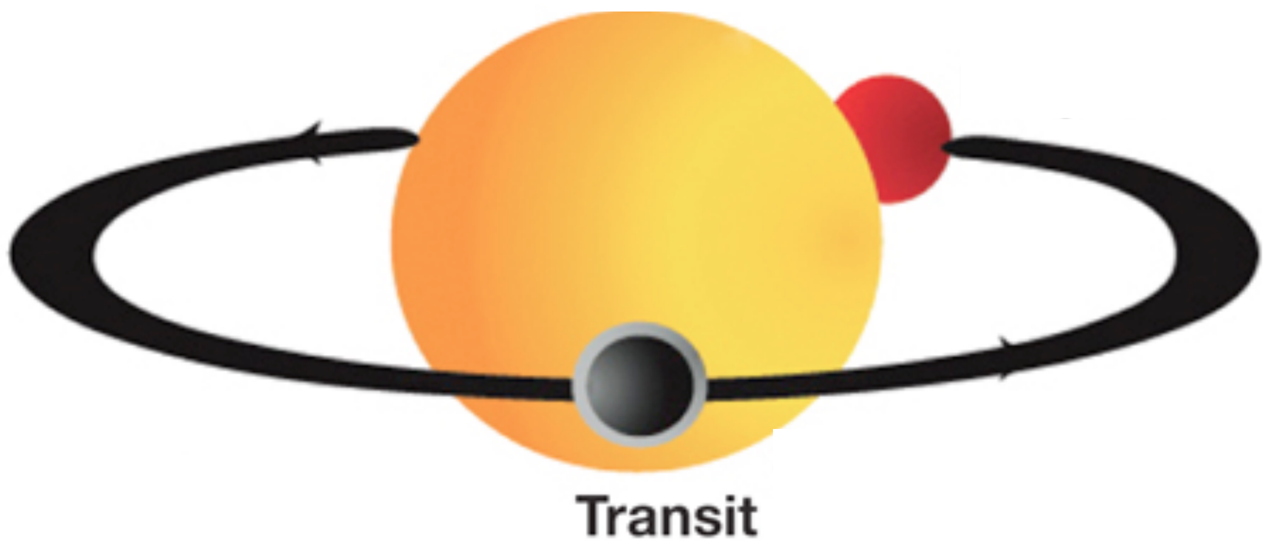
Plan of talk

I) Probing exoplanet atmospheres with ground-based telescopes

II) GMOS' best assets… and results!

III) Future of transiting exoplanet atmospheres with Gemini

Transits allow Studies of Atmospheres that are not possible for Non-Transiting Exoplanets



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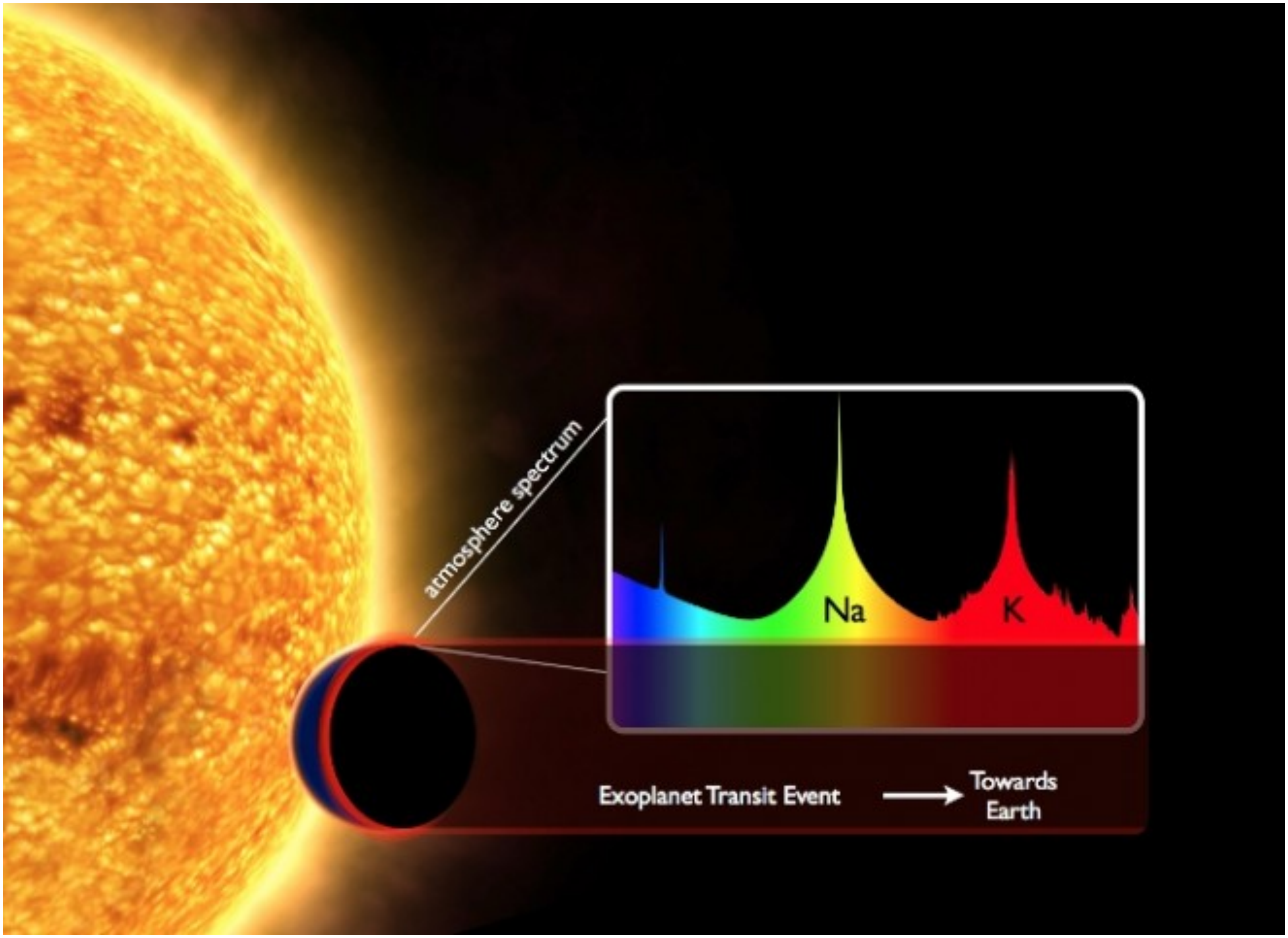
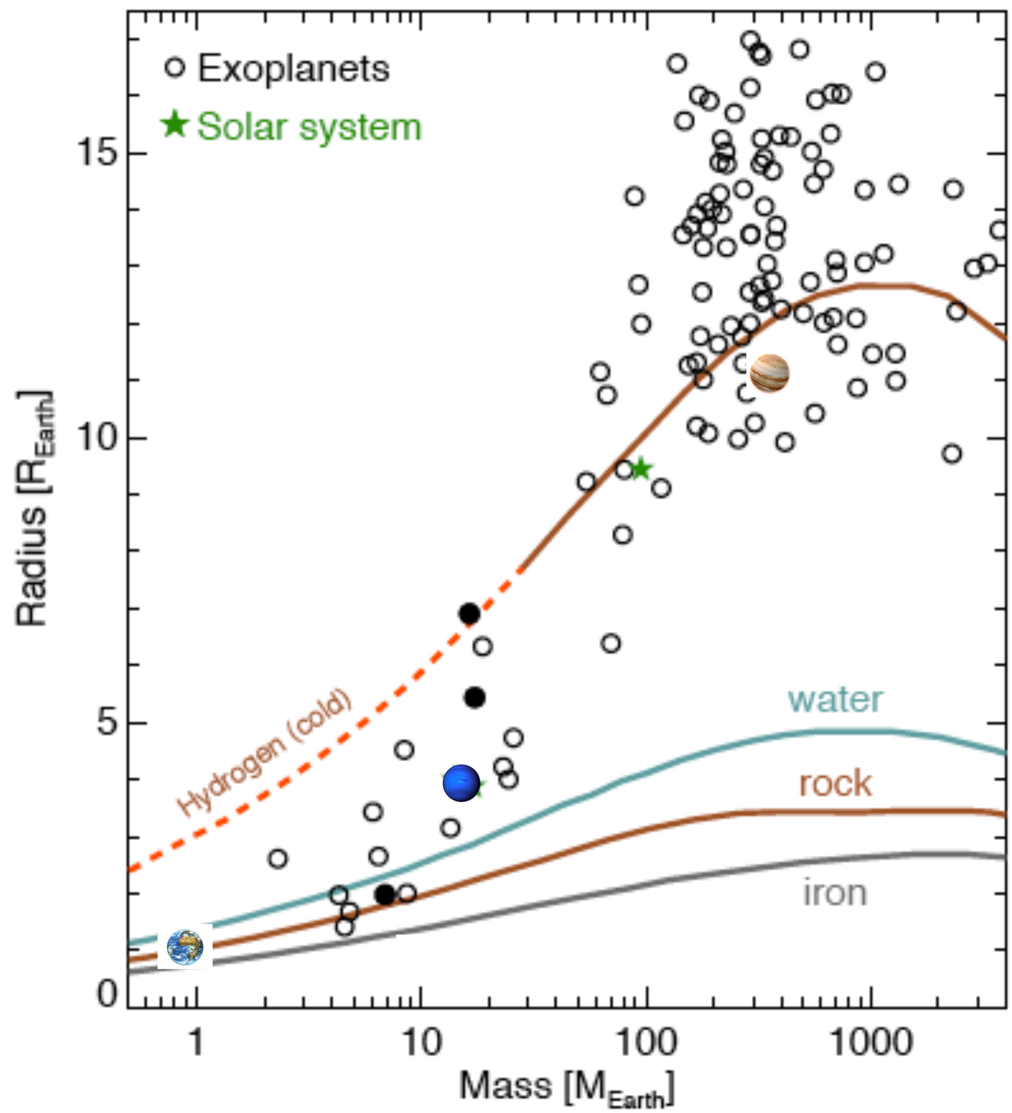


Mass-Radius Relationship for Transiting Planets

Updated from Winn et al. (2011)

Provides basic information on the atmospheres



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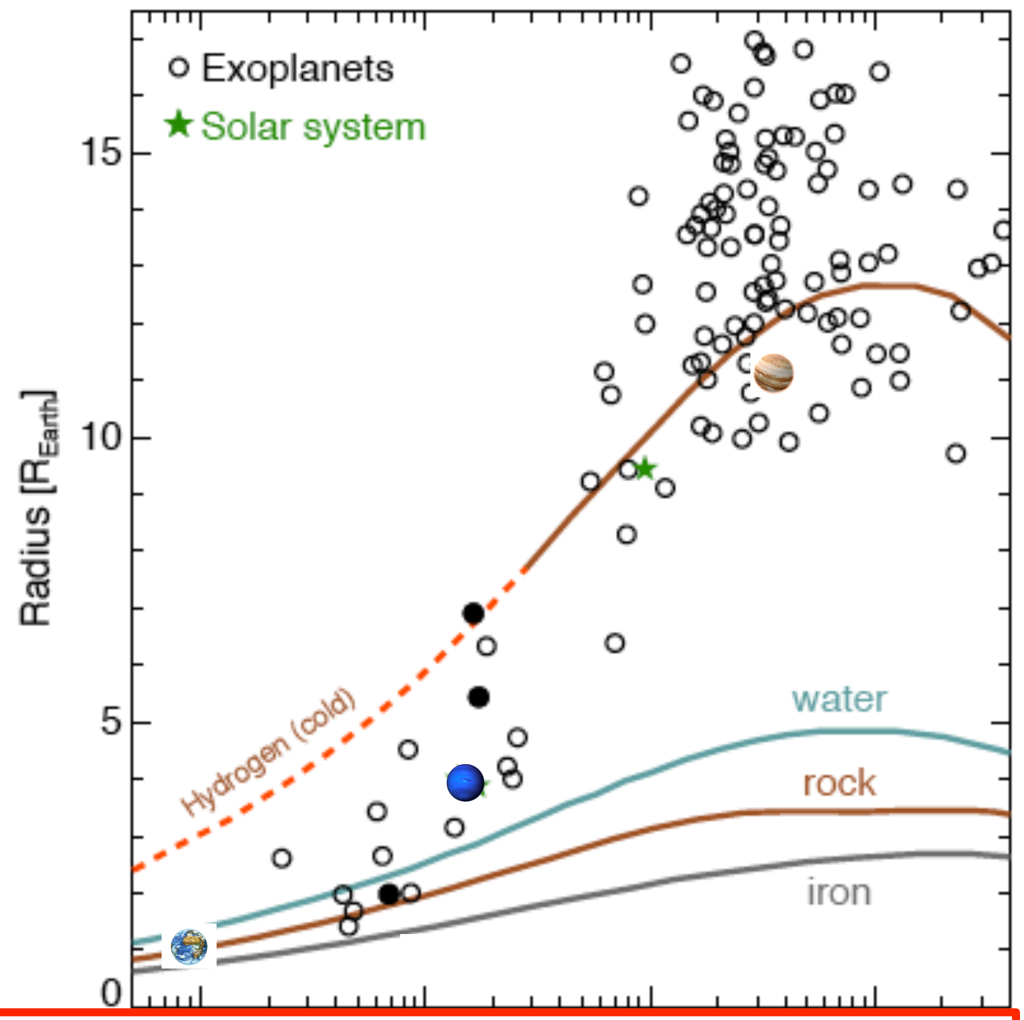


Provides basic information on the atmospheres

<u>Next step</u>: exo-atmospheric composition (atomic, molecular and condensates), metallicity (C/O) and structure (T-P) => Spectroscopy

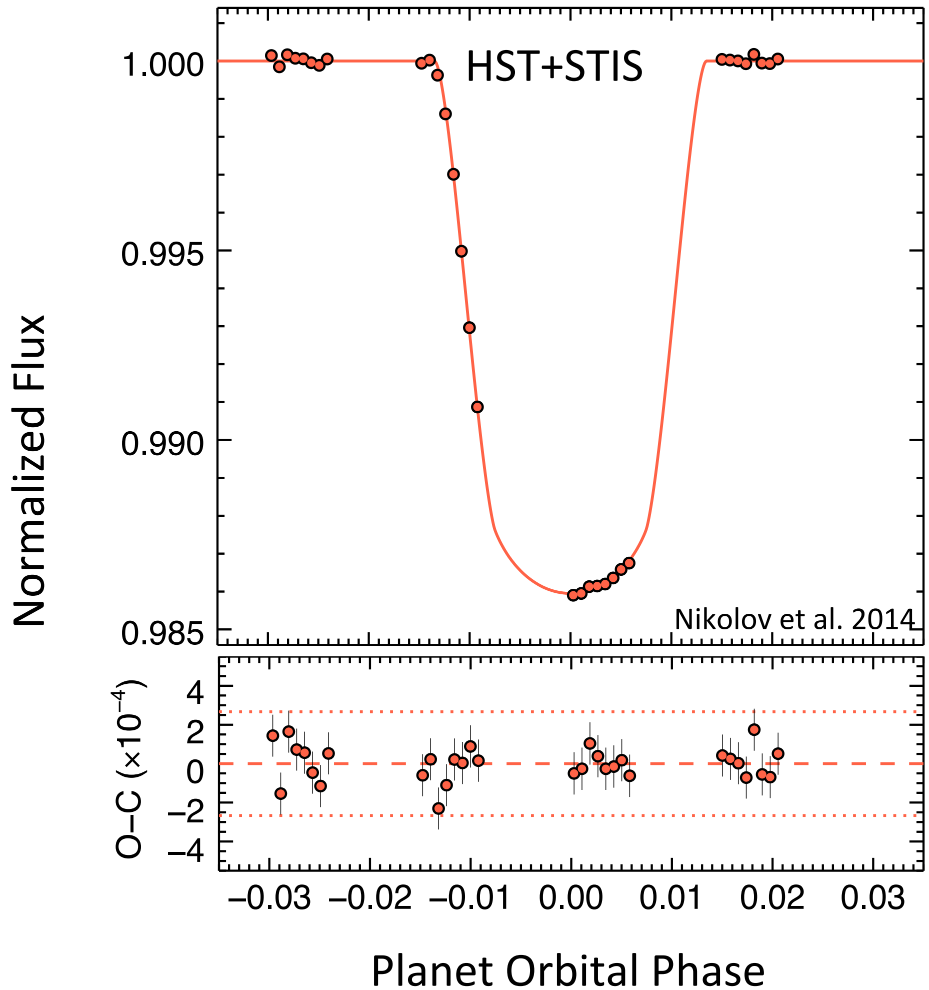
Exoplanet characterisation

Fundamental Questions We Would Like to Answer

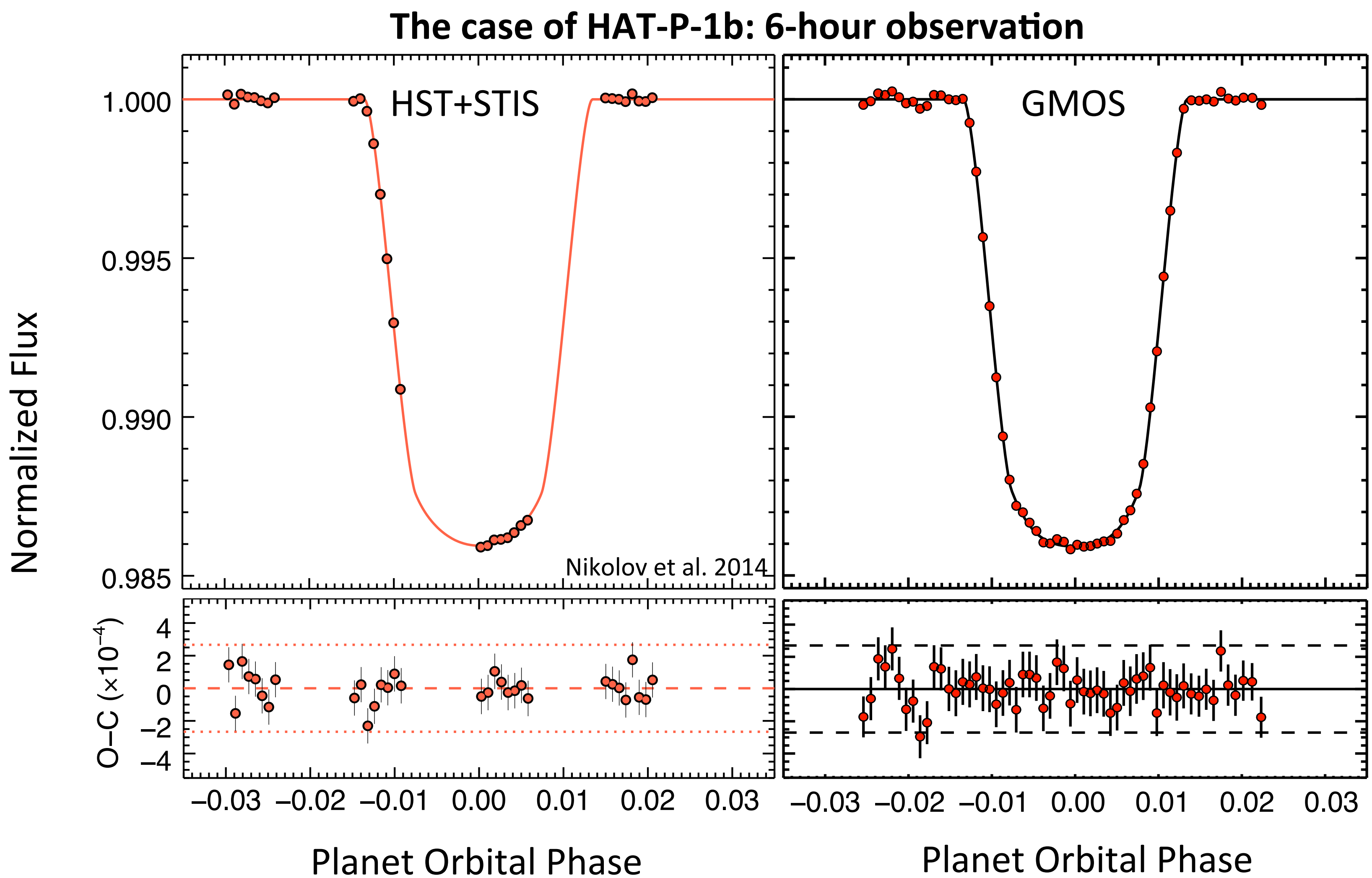
- Nature and physical properties of planetary systems detected? (test planetary physics in new regimes)
- Planetary formation: where and how planets form?
- Study of a new class of astronomical objects: what are the family of properties?
- How they compare to the Solar-System?
- Developing the tools to study Earth analogs

Spectroscopy from space telescopes

The case of HAT-P-1b: 6-hour observation

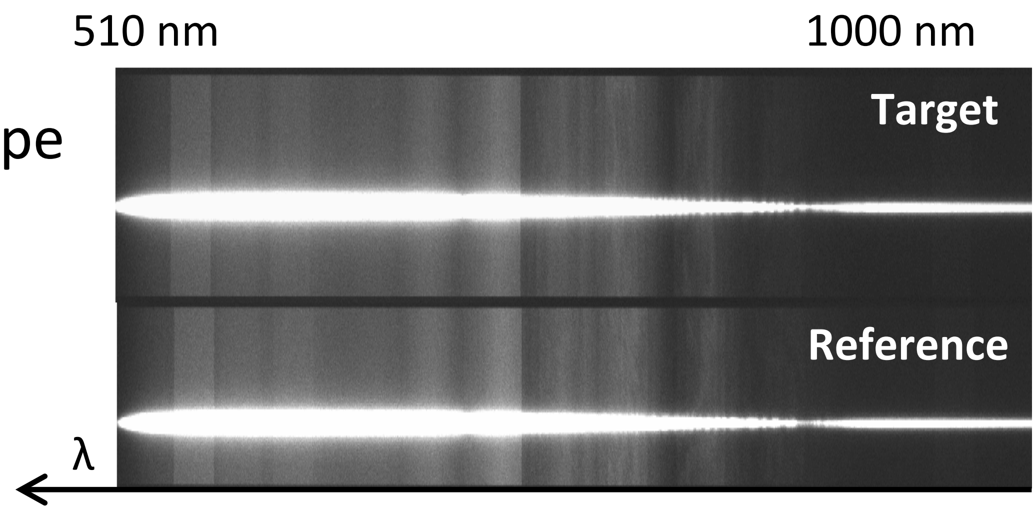


HST vs Gemini/GMOS



MOS Technique

- Target + reference stars: same magnitude & spectral type
- This technique allows us to correct for systematics wavelength by wavelength
- Wide 12” slit to improve spectrophotometric precision (avoid slit losses)



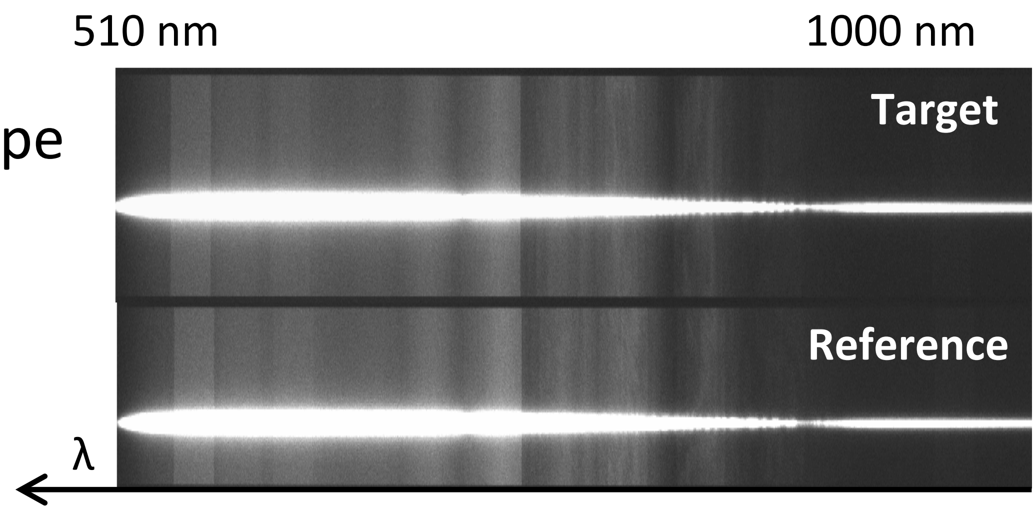
MOS Technique

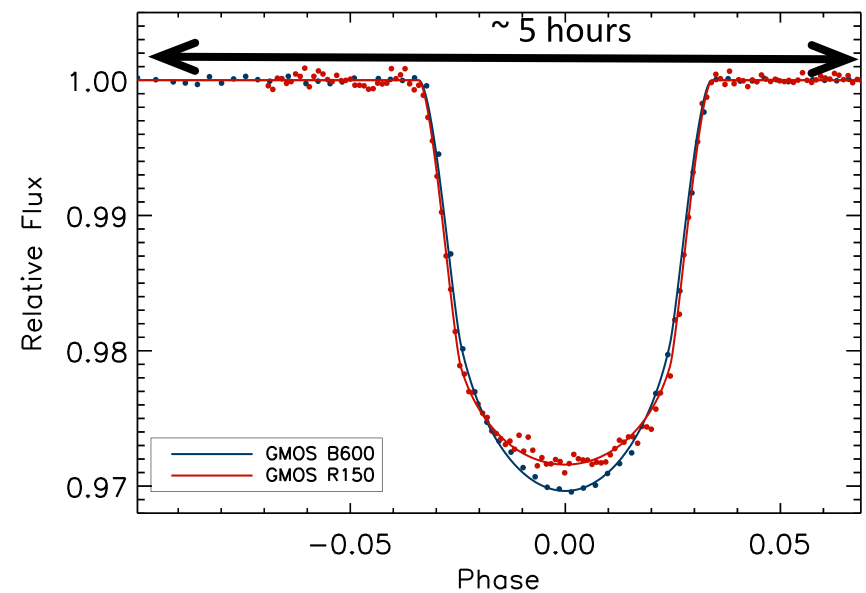
- Target + reference stars: same magnitude & spectral type

- This technique allows us to correct for systematics wavelength by wavelength

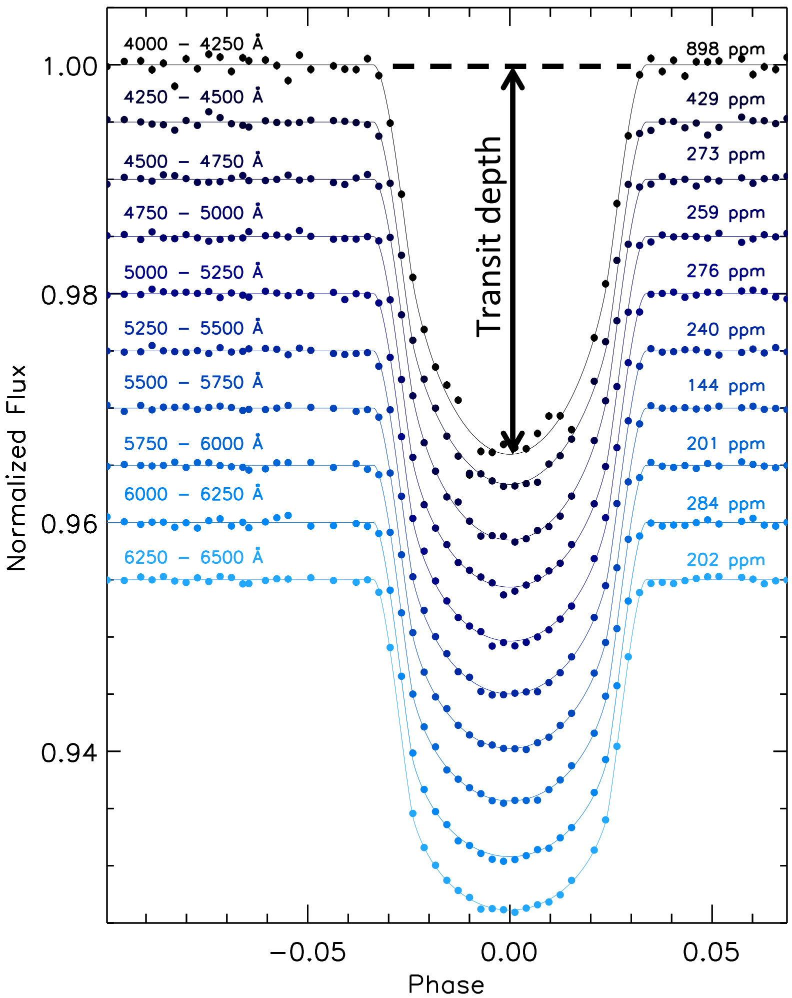
- Wide 12” slit to improve spectrophotometric precision (avoid slit losses)

- We get a frame every ~ 50 s and build transit lightcurves





How to Extract Exoplanet Spectra



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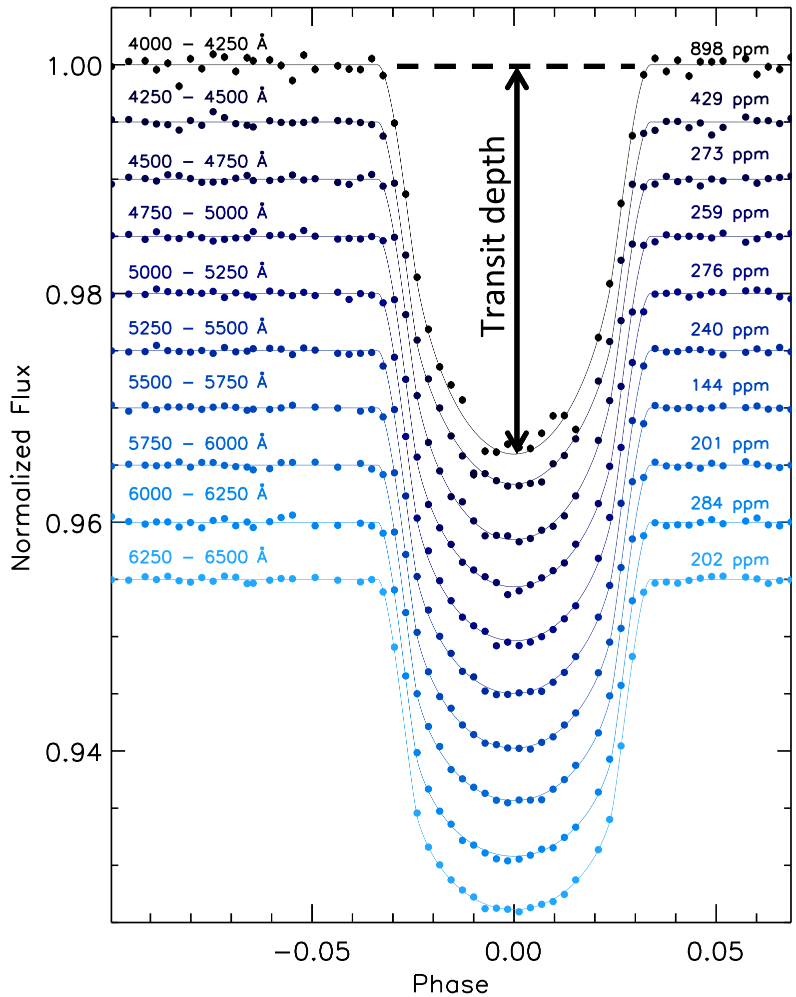
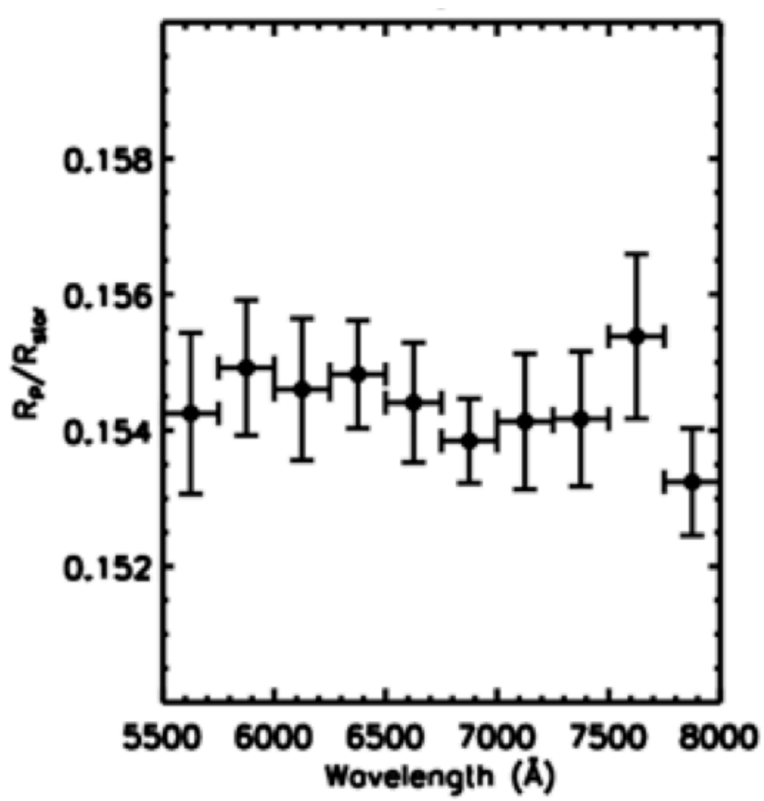
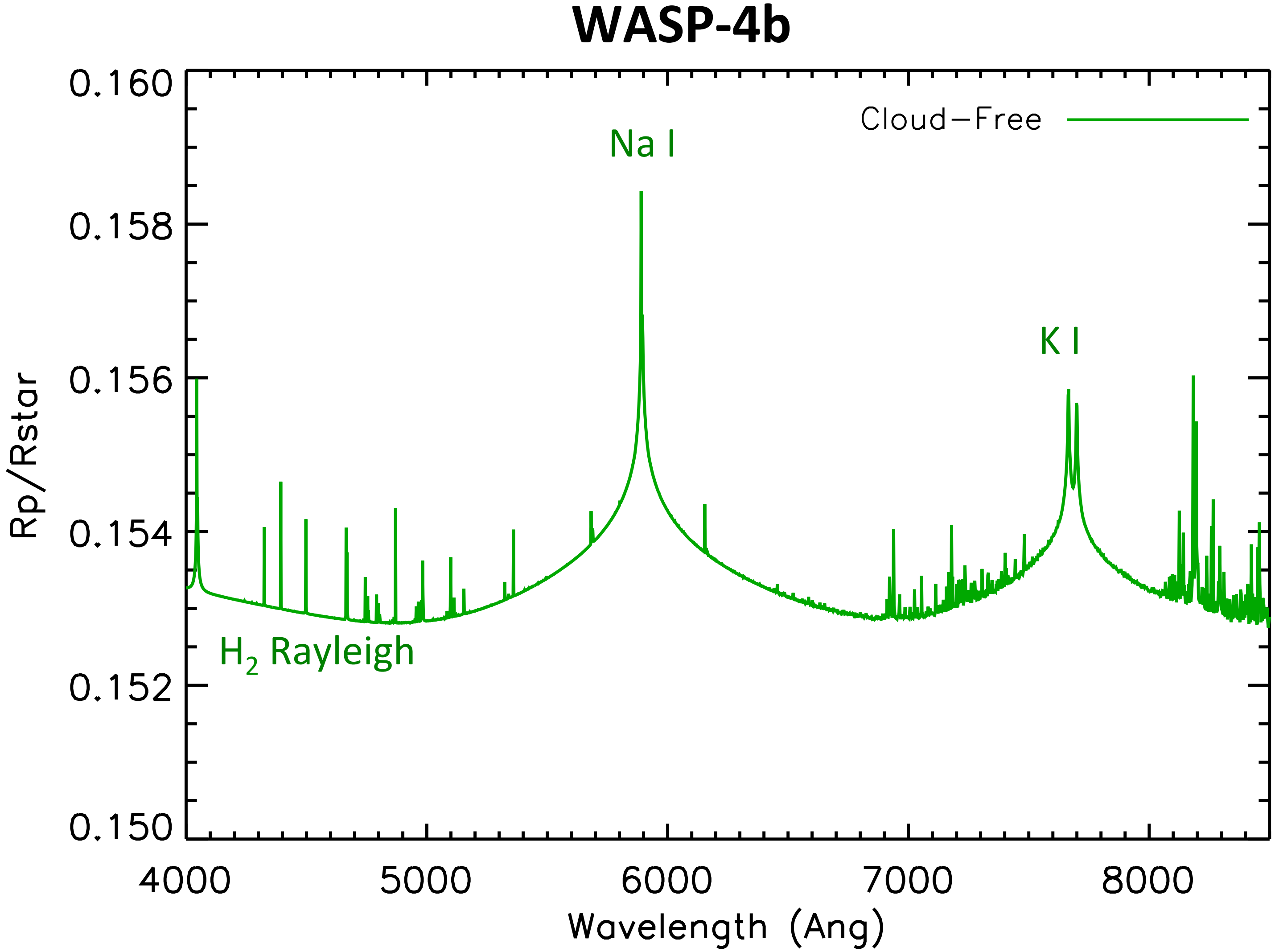




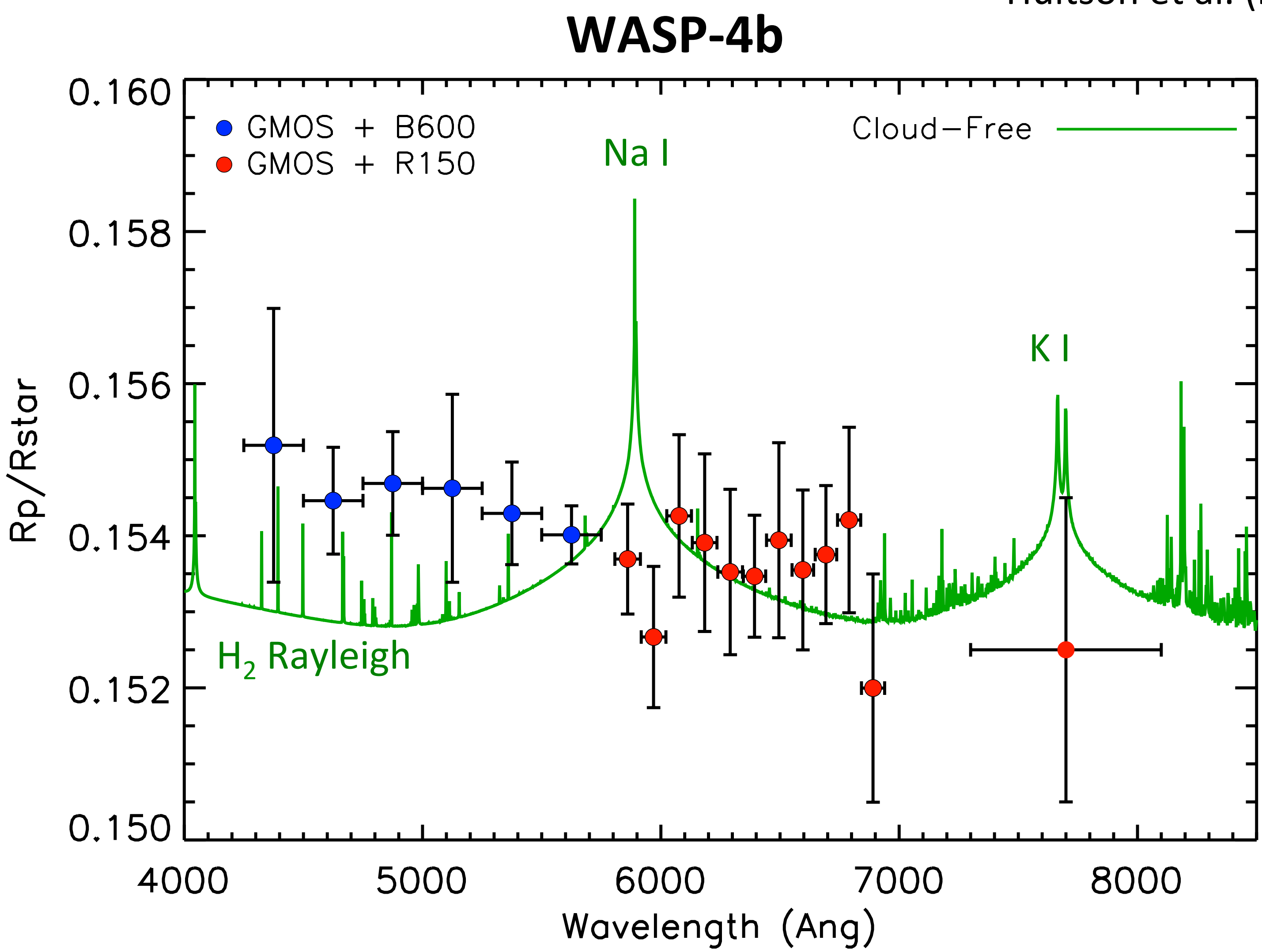
Comparison with models

Models from J. Fortney



Comparison with models

Huitson et al. (in prep.)



Cloud-Dominated hot-Jupiters

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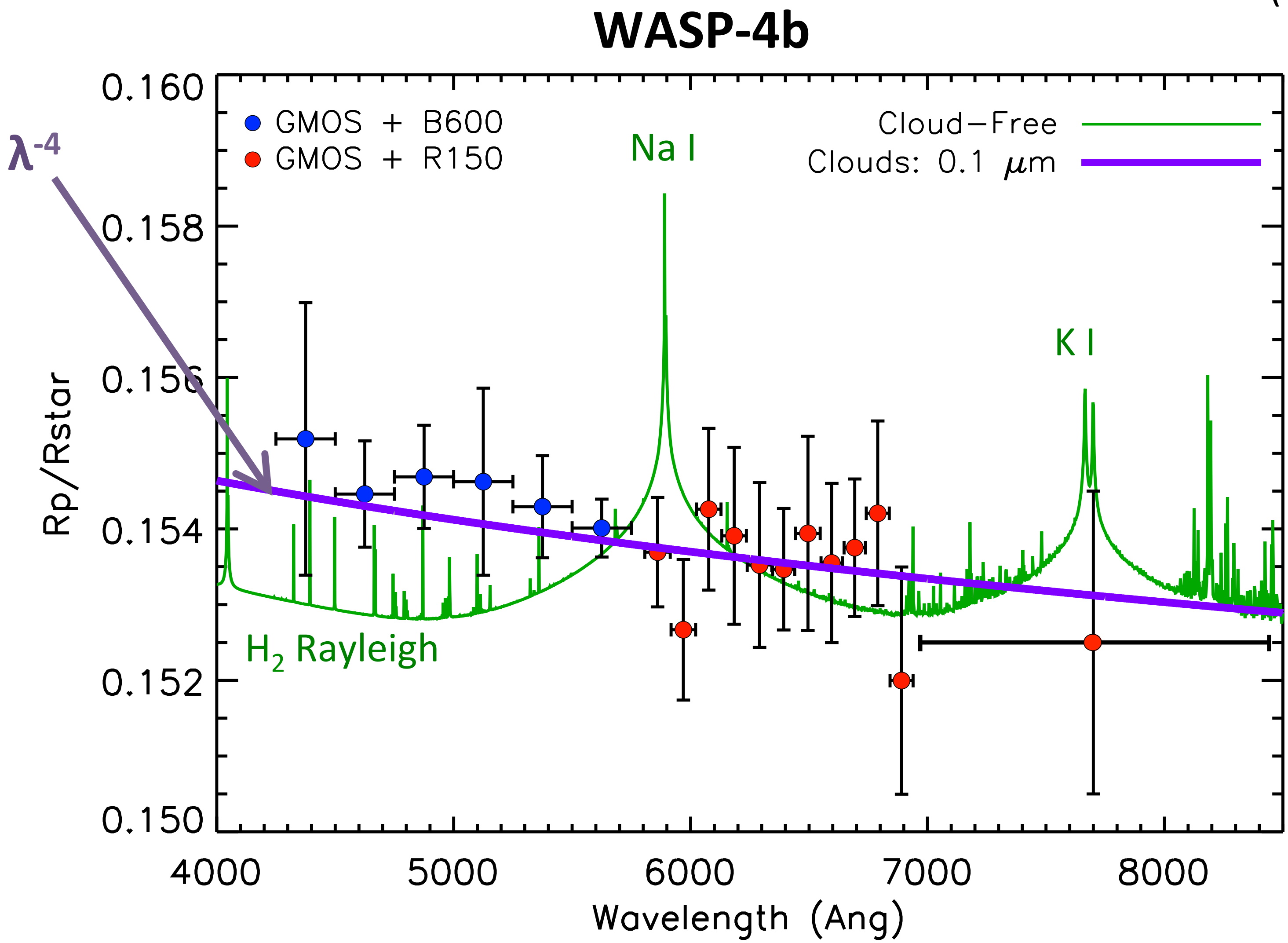
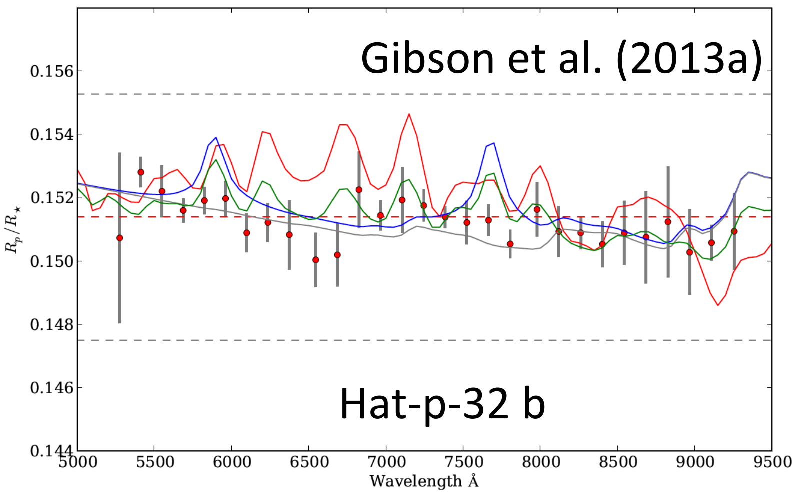
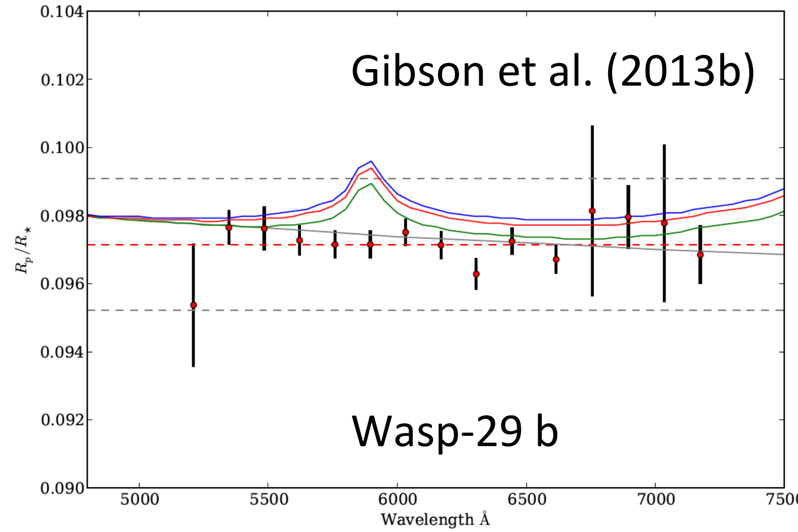
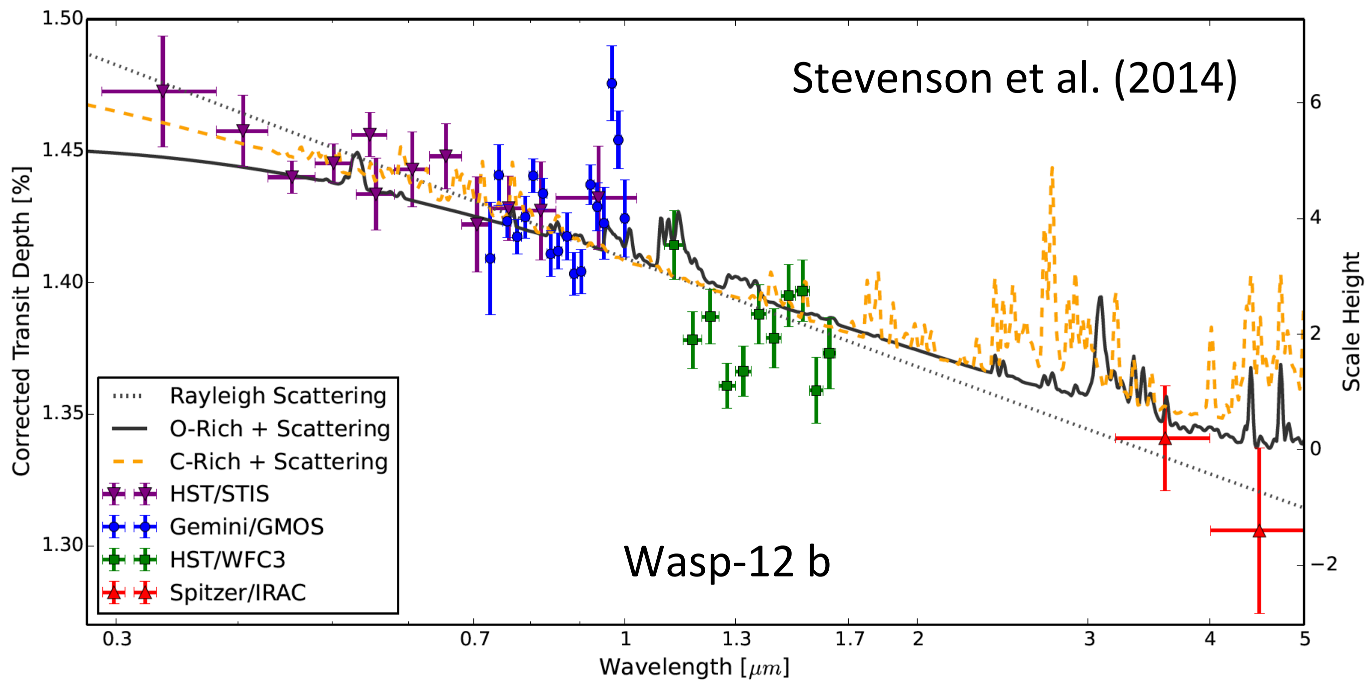


Previous results on hot-Jupiters







First Ground-Based Survey of exo-atmospheres (GMOS)

P.I. Désert

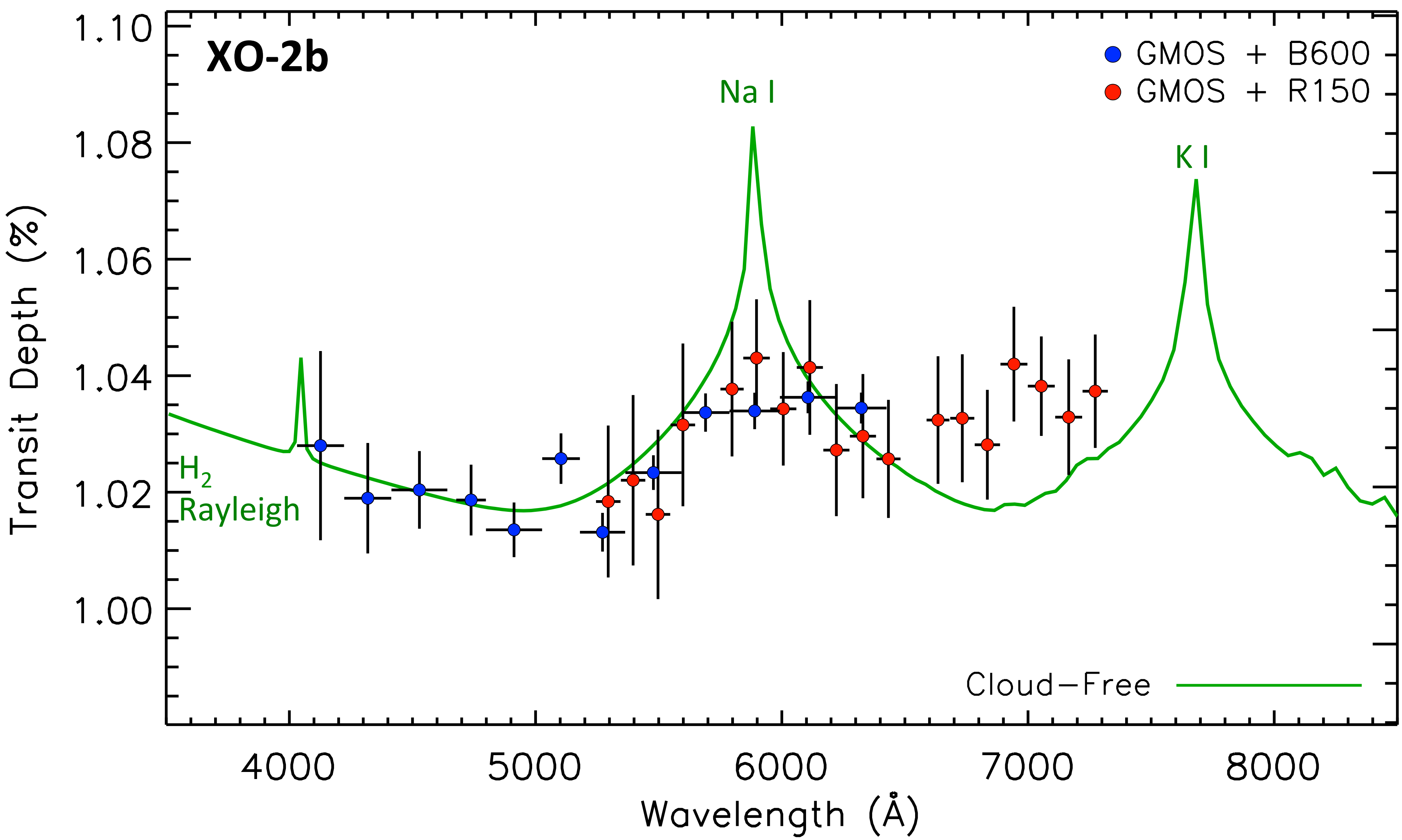
- **<u>What?</u>** Comparative exoplanetology
  - Probing atomic (Na, K), molecular (H_2O, TiO, VO) species
  - Cloud-free or cloudy?
- **<u>How?</u>**
  - MOS Transmission Spectroscopy (photometric precision).
  - 9 Objects (8 <Vmag<11)
  - Observe and re-observe transits of individual objects.
- **<u>Why?</u>**
  - Understanding instrumental and observational systematics
  - Interpretation of the spectra can be challenging

Why Gemini/GMOS?

- Ground-based, 8m telescopes
- Multi-Object optical spectroscopy
- Large 5 x 5 arcmin FOV
- Fully-sky coverage with both GMOS instruments
- Queue mode, eavesdropping

XO-2b: Detection of Na

Désert et al. (in prep)



XO-2b: Cloud-Free

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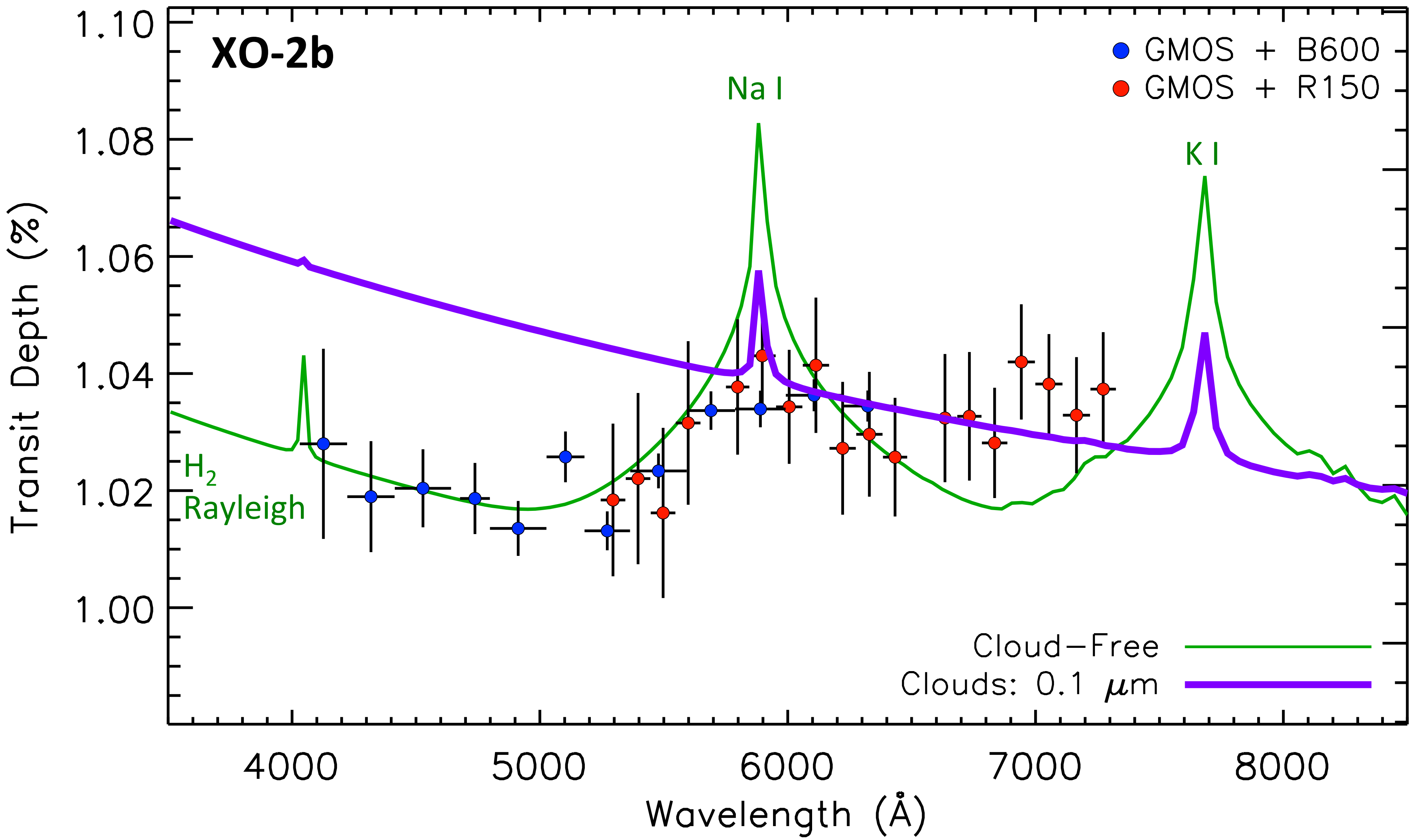
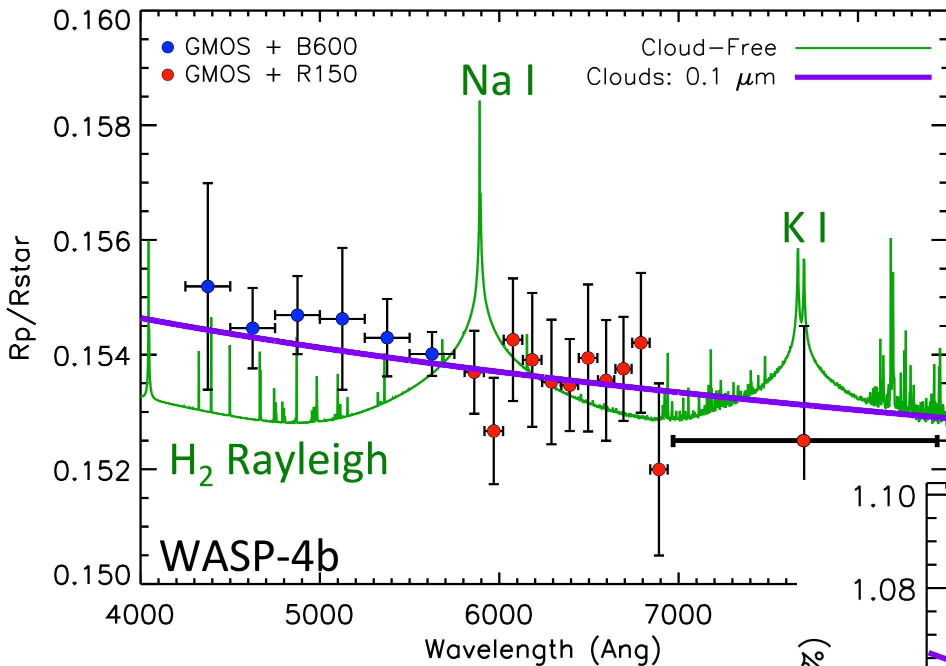


First Results from GMOS Survey

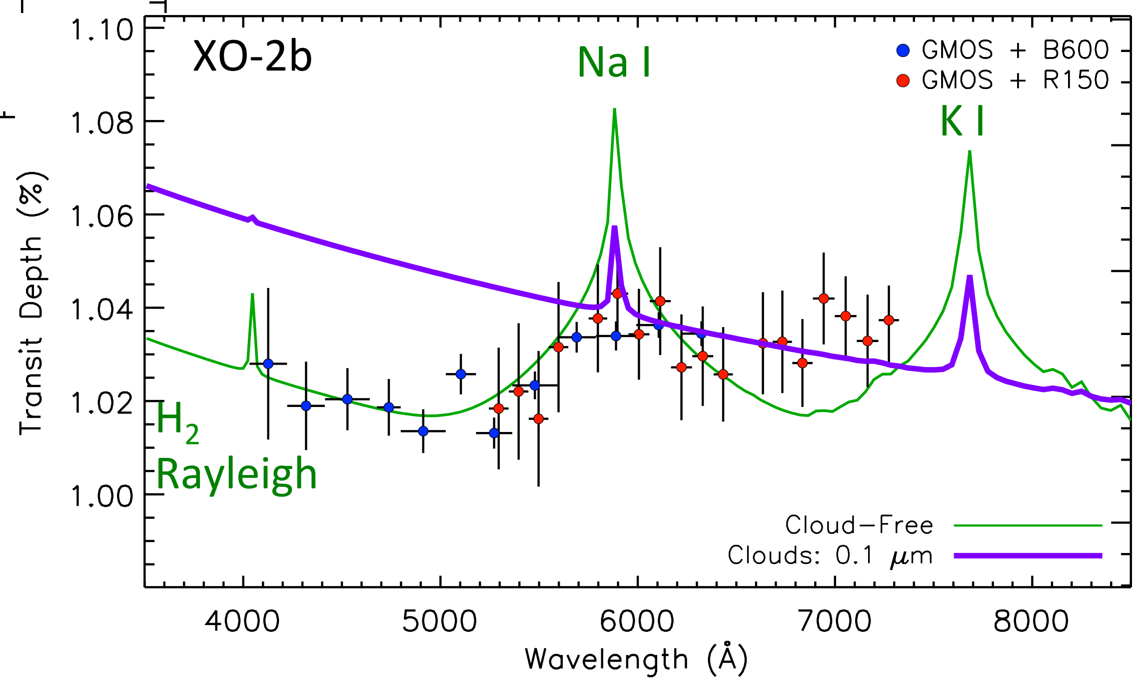
Clouds detected



First Important Result

Two planets similar, yet two different signatures => diversity

No Clouds, detection of Na



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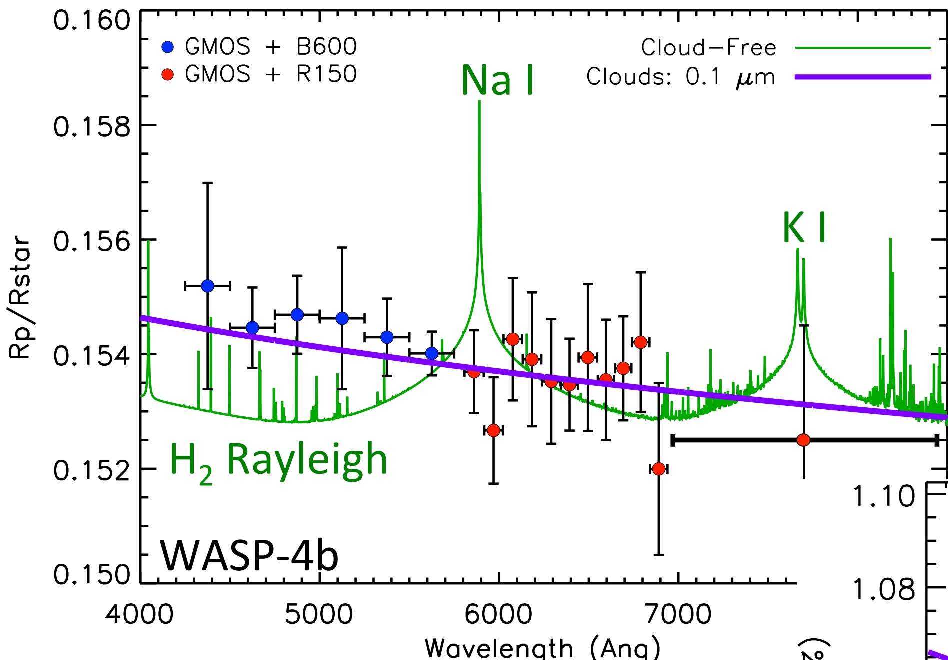

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New survey awarded (B600)
PI Huitson
2015B -> 2017A (24hrs/sem)

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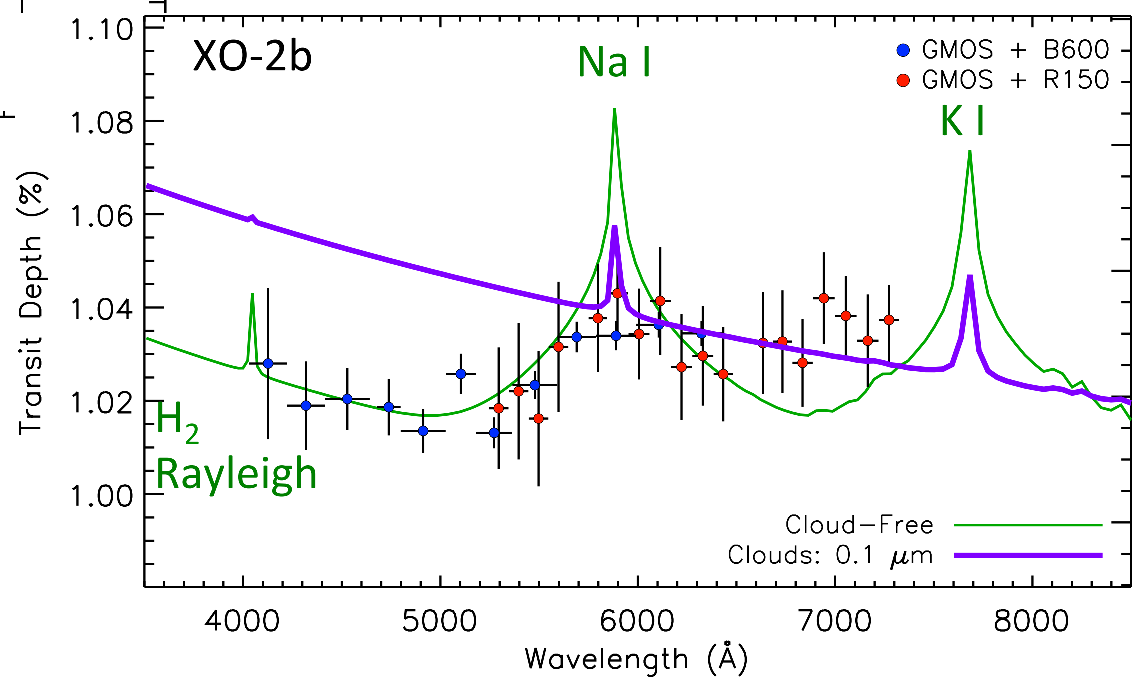


Numerous Challenges to Overcome

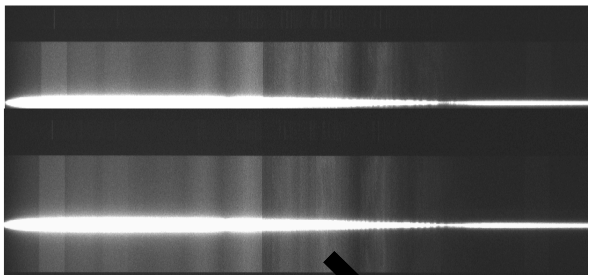
- **Requirement**:   100 ppm/10 nm

- **Variability:** instrumental, observational, astrophysical (the key is to control and understand these variations).

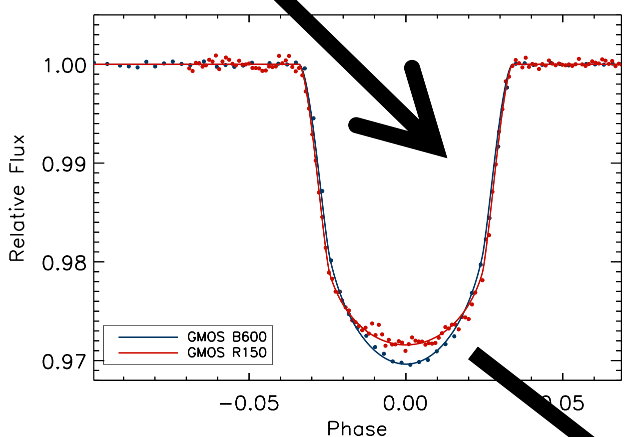
- **Detectors:** cosmetics, fringing (10%), new detectors significantly improve results! (cf. poster by K. Roth et al.)

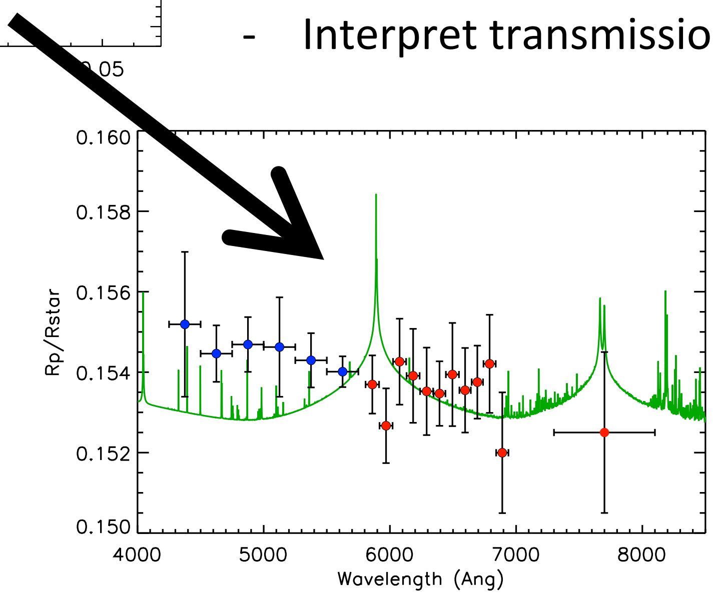
- **Scheduling and observing transits:** few events per year (for hot-Jupiters!), and observing during 4-7 hours!!!

Analysis pipeline online this fall (v1.0)



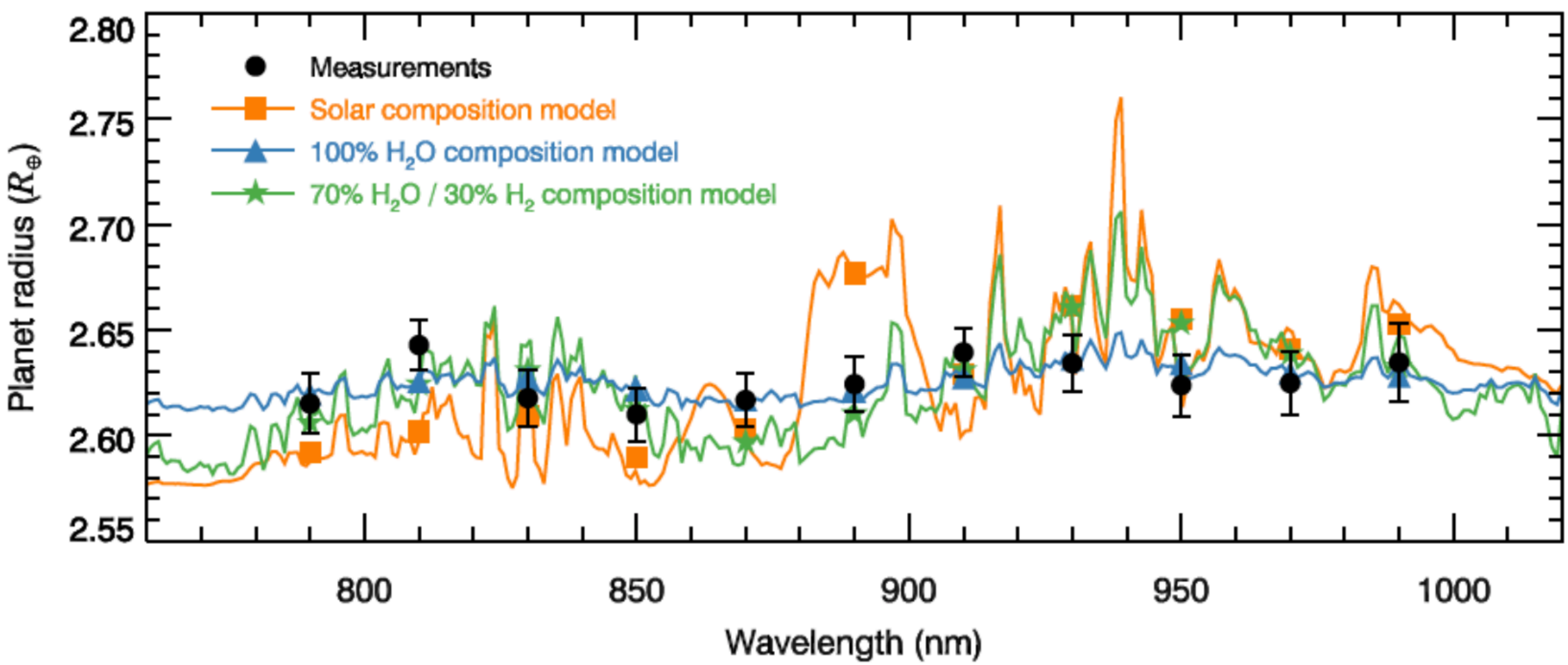
- Standard 2D image processing but to high precision
- De-tilting
- Correct electronic errors in columns
- Spectral extraction
- Wavelength calibration
- Cross-correlation in time
- Characterize fringing
- Optimize transmission spectral binning
- Fit transit lightcurves
- Interpret transmission spectra with models





Super-Earth (GJ1214b)

Bean et al. (2010)



MOS for Exoplanet Atmospheres

Current picture (GMOS in context):

- VLT/FORS (Bean+10, Boffin+15), back this semester
- GMOS (Gibson+13ab, Stevenson+14)
- Magellan/IMACS (Jordan+13)
- Keck/DEIMOS

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Strength of GMOS:

Q-scheduling, eavesdropping, new detectors, full sky

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Future ?

- Stabilized MOS
- Multi-wavelength (blue and red arms)
- Fast readout (bright stars from NASA/TESS)
- Fast turn over proposals for any events
- Scheduling best events
- ELTs, GMT, TMT, but also 8-10m class telescopes

Near-Future of GMOS for exoplanets

GEONIS

(Gemini Efficient Optical and Near-infrared Imager and Spectrograph)

PI/PM N. Konidaris (see GIFS presentation this pm)

A workhorse instrument for exo-atmospheres:

- Optical + NIR spectrograph
- Wide FoV (12’ diameter)
- High throughput
- Stabilized (Flexure compensation system)
- High duty cycle EMCCDs (4k x 4k)
- R ~ 4000

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