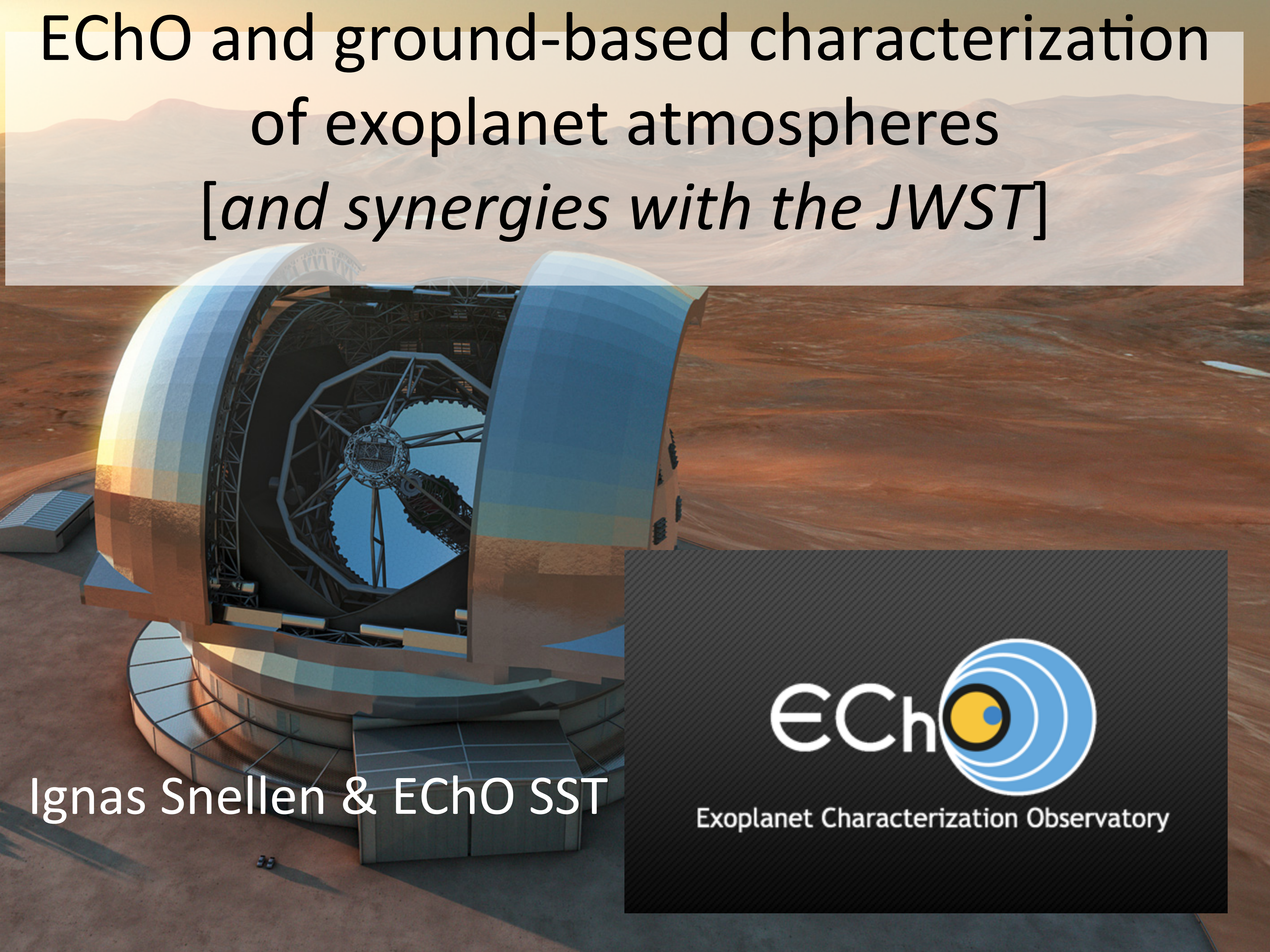
EChO and ground-based characterization of exoplanet atmospheres [*and synergies with the JWST*]



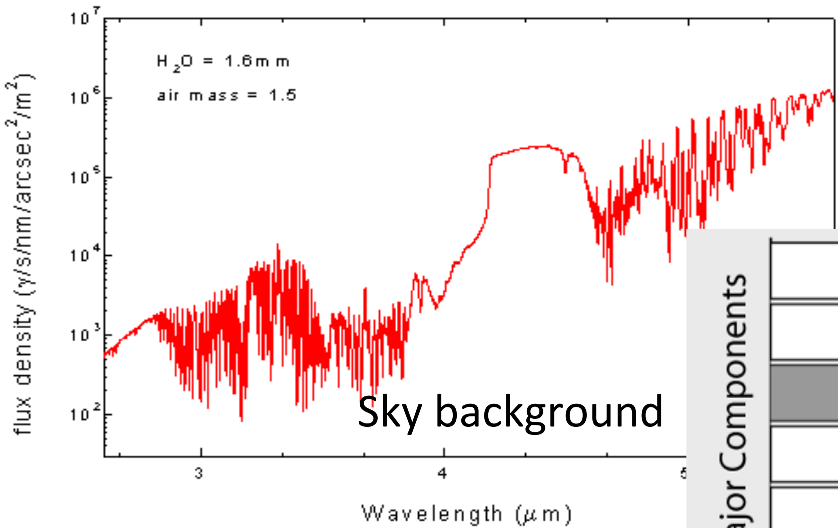
Ignas Snellen & EChO SST

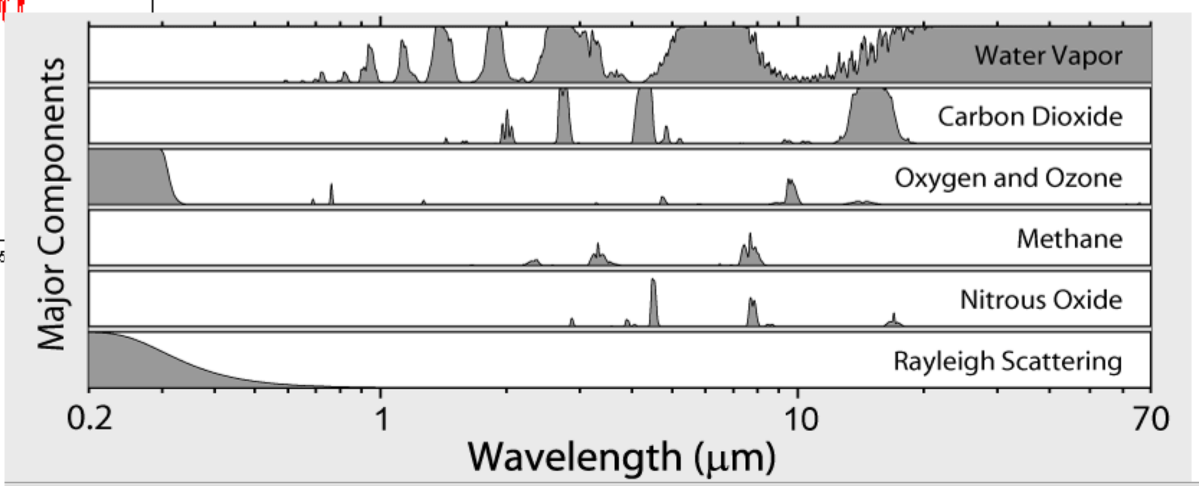
EChO

Exoplanet Characterization Observatory

Groundbased observations of exoplanet atmospheres: many challenges and limitations

- Large parts of the EM-spectrum are blocked from view
- Calibration is challenging!
  - telluric absorption (variable, and directionally dependent)
  - atmospheric seeing
  - instrument stability (rotation angle / gravity vector / thermal)
- Thermal sky-background, >5 micron





Ground-based exoplanet characterization only possible in very specific ways.

-→ *Calibration required at 10^{-3-4}, or better…*

1. Multi-object photometry/spectroscopy

   Uses nearby stars to calibrate telluric absorption

2. High-resolution (R=100,000) spectroscopy

   Spectrally resolves telluric absorption, which is calibrated out

[3. High-contrast imaging]

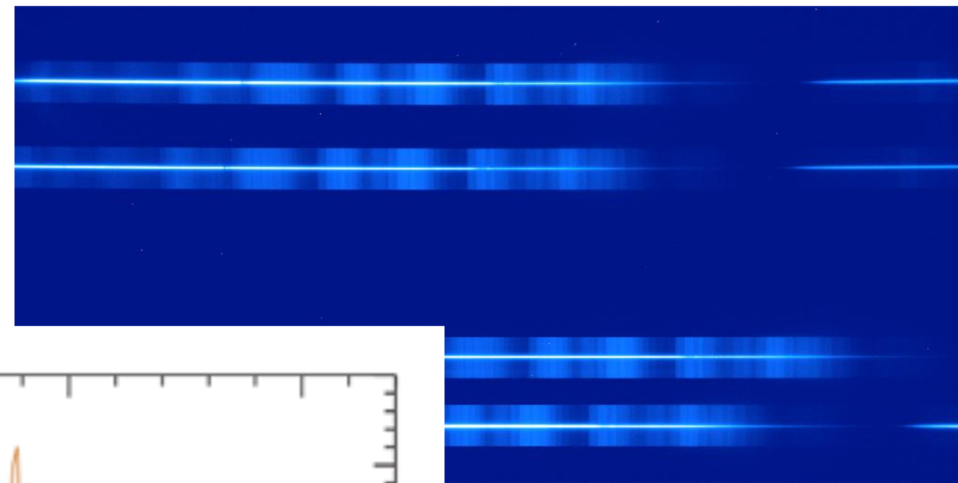
   So far, mainly very young systems. Very exciting, but less relevant to EChO

Multi-object photometry/ spectroscopy

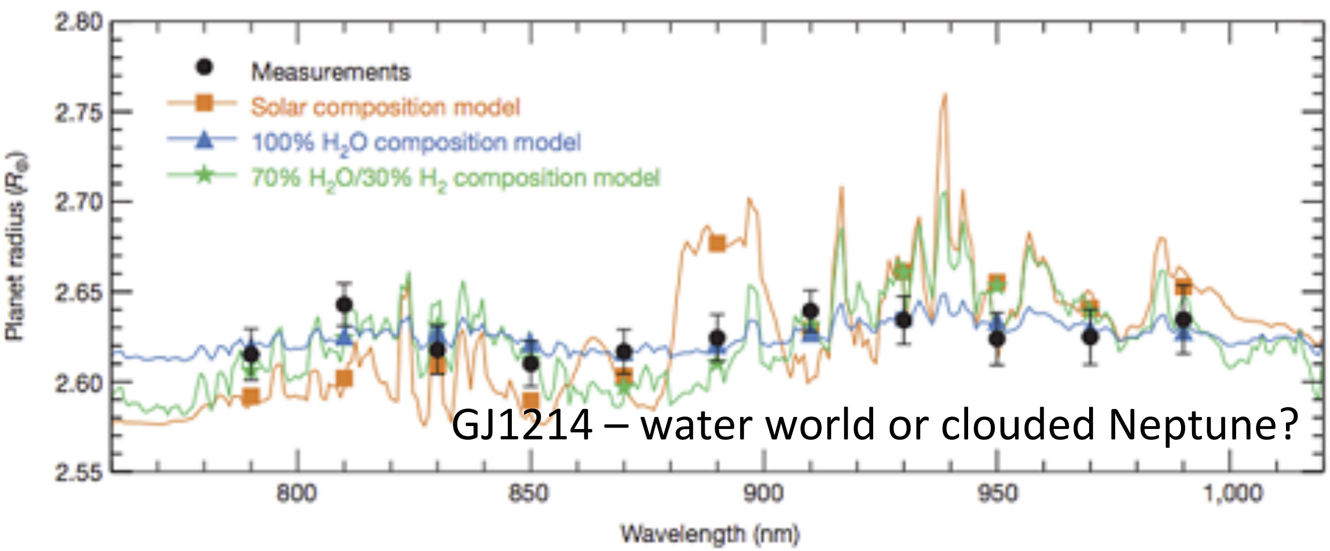
→ Requires nearby reference stars

→ Differential instrumental effects(?)

→ ELT well suited for planets transiting M-dwarfs



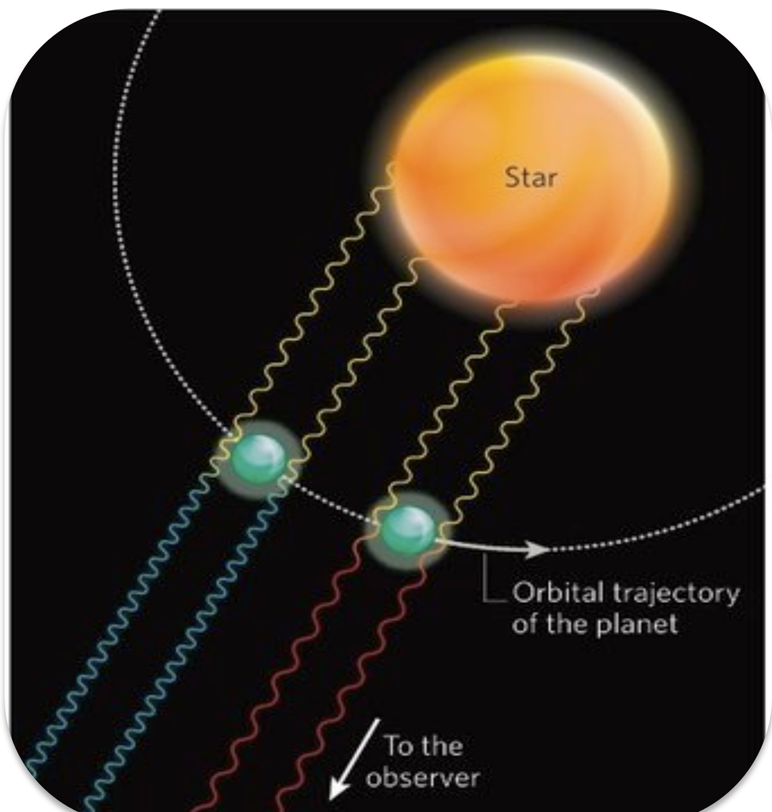
Recent successes with FORS@VLT
 (Bean et al. 2010)

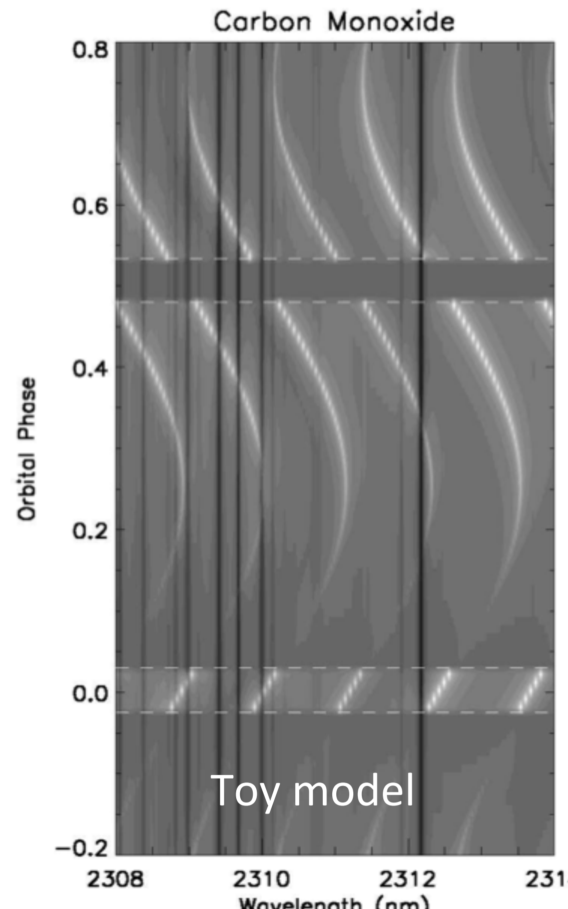


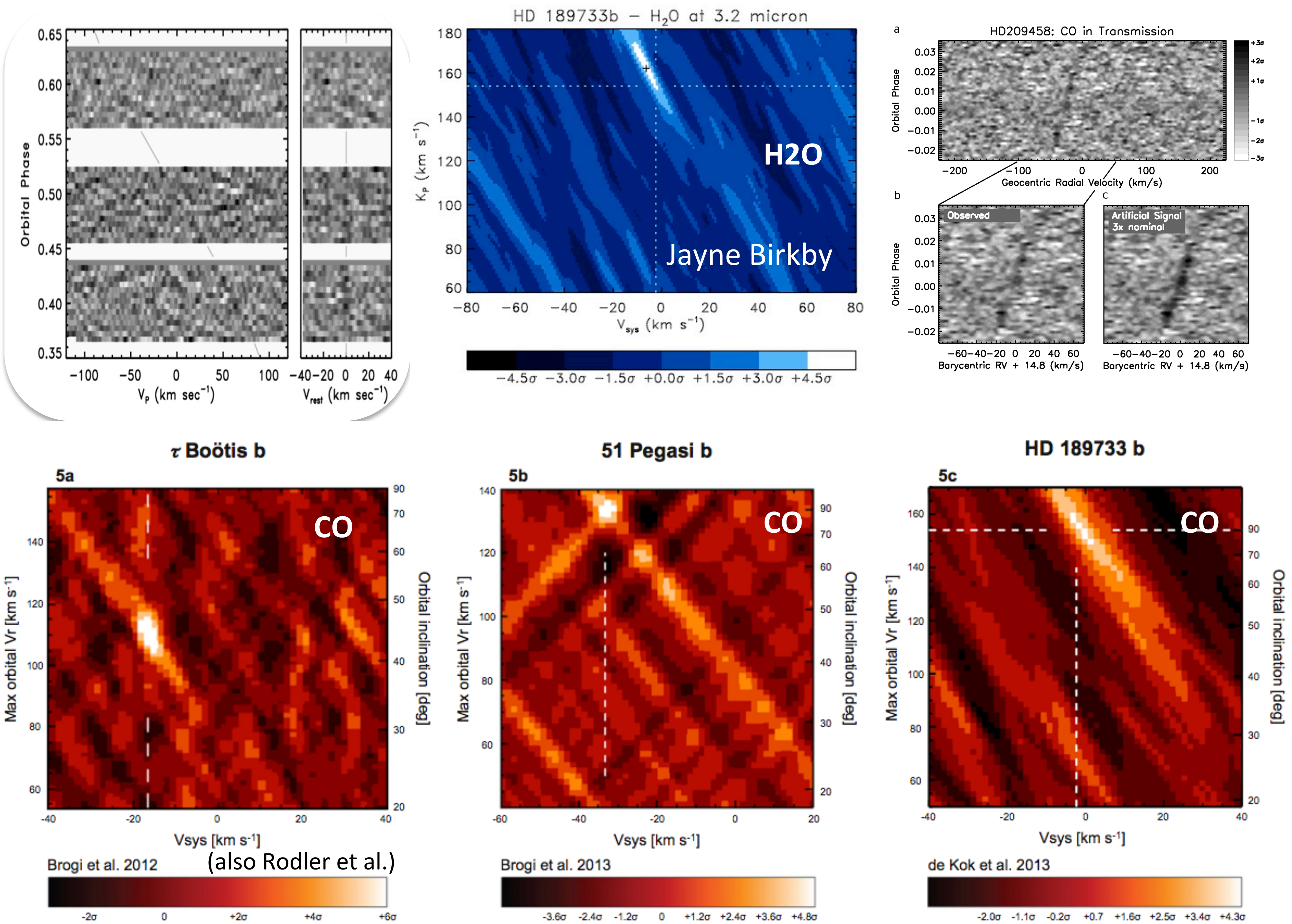
GJ1214 – water world or clouded Neptune?

R=100,000 spectroscopy

- Molecular bands are resolved in tens of individual lines
- Orbital motion of planet (upto >150 km/s) → strong Doppler effects
- Moving planet lines are distinguished from telluric + stellar lines
- No reference stars required






HD 189733b – H_2O at 3.2 micron
H2O
Jayne Birkby
HD209458: CO in Transmission
Observed
Artificial Signal 3x nominal
τ Boötis b
51 Pegasi b
HD 189733 b
CO
Brogi et al. 2012
(also Rodler et al.)
Brogi et al. 2013
de Kok et al. 2013

The planned ELTs and their capabilities

Telescope	Diameter	Instrument	Spectral Range	Instant coverage	spectral dispersion
E-ELT	39 m	METIS	2.9-5.3 μm	0.1 μm	R=100,000
		HIRES	0.4-2.3 μm	0.4-2.3 μm	R=100,000
		MOS	0.4-1.7 μm	0.4-1.7 μm	R<30,000
GMT	24.5 m	MOS	0.4-1.0 μm	0.4-1.0 μm	R<5000
		NIR-HRS	1.0-5.0 μm	?	R~50-100,000
		G-CLEF	0.4-1.0 μm	0.4-1.0 μm	R=100,000
TMT	30 m	WFOS	0.3-1.0 μm	0.3-1.0 μm	R<7,500
		HROS	0.3-1.0 μm	0.3 -1.0 μm	R~50-90,000
		IRMOS	0.8 - 2.5 μm	0.3 μm	R=2,000-10,000
		MIRES	9-18 μm	8-14 μm	R=100,000
		NIRES	1-5 μm	~2 μm	R=100,000

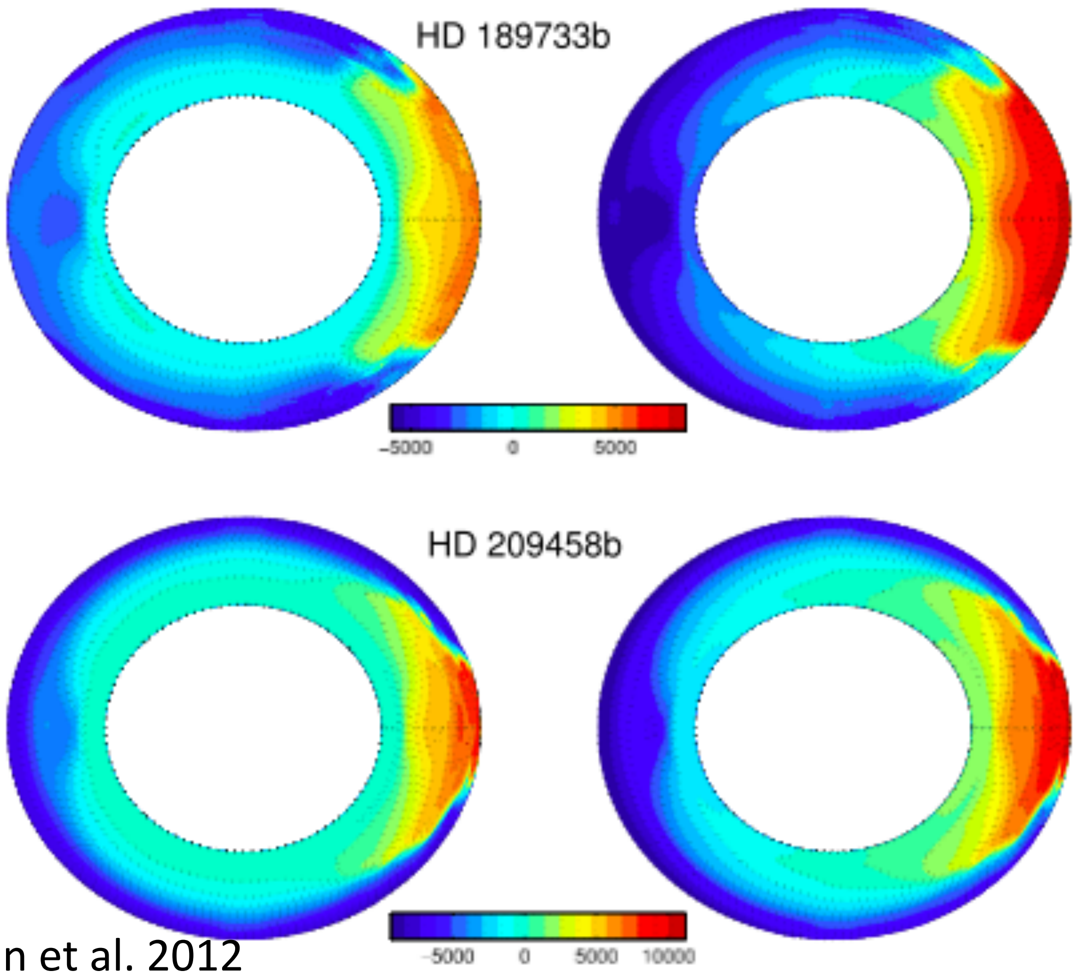
Table 1. Planned next-generation telescopes and their instrumentation relevant to transiting exoplanet characterization science.

Synergies between the ELT and EChO

- ELTs will be highly complementary, relevant and beneficial to EChO
- **EChO Spectra** [obtained over a large instantaneous wavelength range] will measure the most important planet parameters – T/P profiles & chemical abundances.
- ELT spectra can only be interpreted in a useful manner knowing these basic parameters, since high-dispersion observations only measure differential line depths.
- In turn, the **ELTs** can do uniquely detailed observations – greatly beneficial to interpreting and modeling the planets targeted by EChO.

Examples of ELT Science in the EChO era

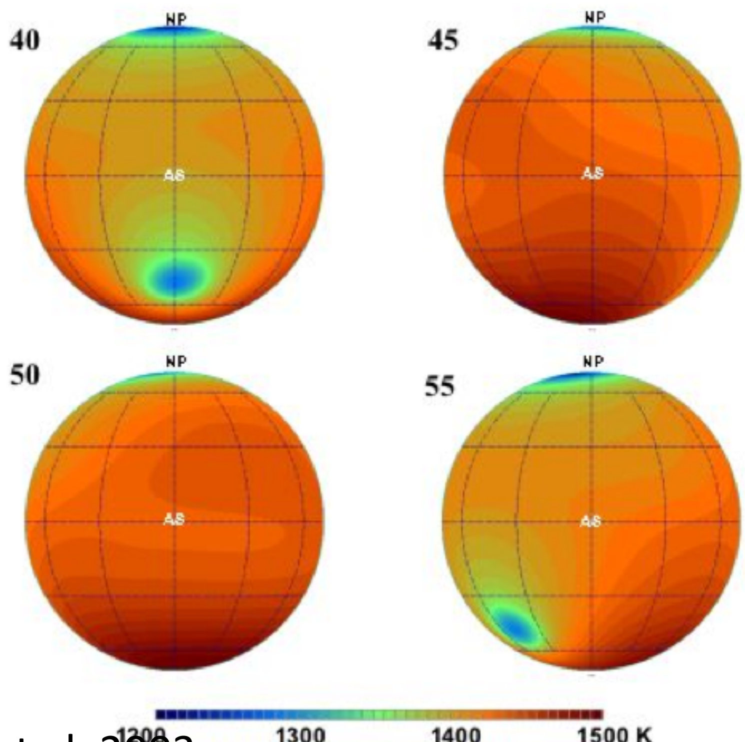
- Line broadening → Planet rotation and circulation



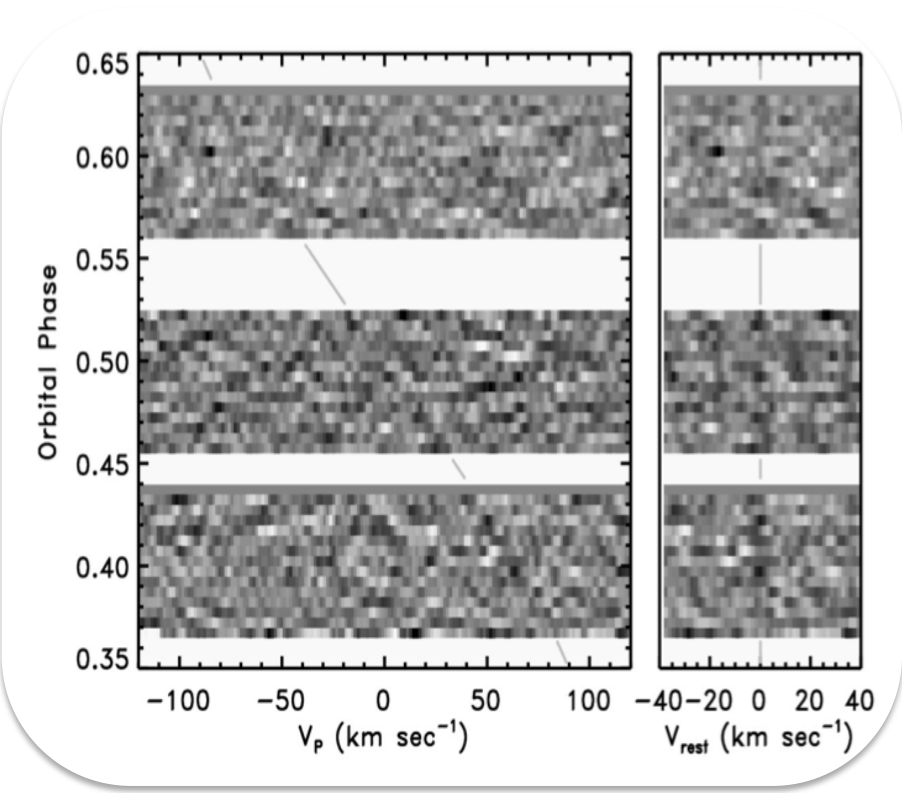
Showman et al. 2012

ELT Science in the EChO era

- Molecular spectra (CO, CO2, H2O, CH4) as function of orbital phase → photochemistry, T/P versus longitude

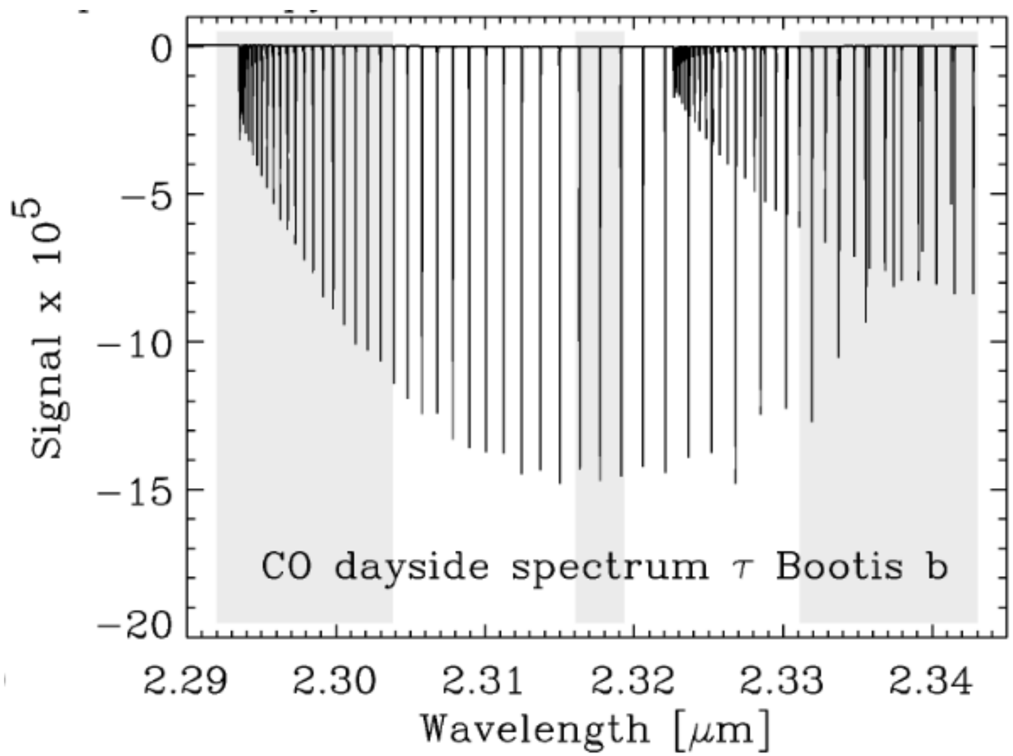


Cho et al. 2003



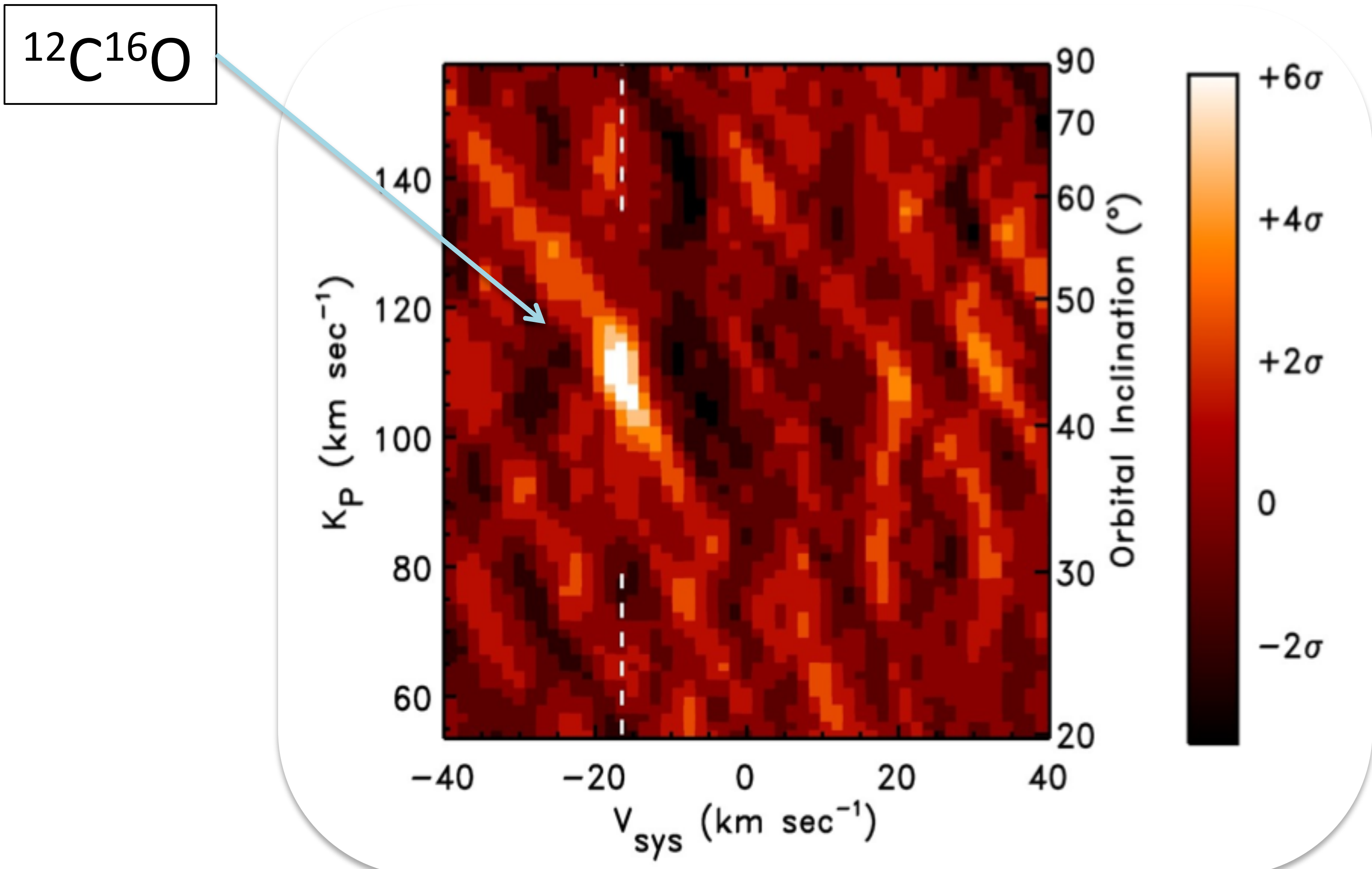
Examples of ELT science in the EChO era

- Determination of orbital inclination for up to 100 non-transiting planets → masses + targets for EChO phase curve measurements
- Detection of the individual lines (instead of ensemble via cross-correlation) → help to constrain T/P profile; detections of inversion layers



ELT Science in the EChO era

- Isotopologues? → evolution of planet atmosphere



EChO in the context of the JWST

- Largest space telescope ever conceived - 22 m^2 collecting area
- True observatory with multiple capabilities, instruments and operation modes.
- Scheduled for launch in late 2018.
- Although primarily designed to observe extremely faint targets - JWST will do a great deal of ground-breaking exoplanet science

Power of EChO

1. it is a dedicated survey telescope – census of 200+ planets
2. It has a large instantaneous wavelength coverage – crucial for transit spectroscopy

EChO in the context of the JWST

- Dedicated survey telescope versus multi-purpose observatory

→ Optimized for high-precision bright-star spectroscopy

→ Dedicated telescope allows a large census of hundred(s) of planets – impossible with the JWST.

- Hopefully there will be significant overlap (in time) between EChO & JWST.
- EChO can point the JWST to the most interesting & varied targets.
- JWST can likely observe tens of interesting targets in specific wavelength regimes.

EChO in the context of the JWST

Large instantaneous wavelength coverage:

The JWST will need a number of wavelength settings to cover the 0.5-11 micron wavelength range. The brighter the star – the more settings required.

Stellar variability is a real issue!

- Gluing spectral pieces together for secondary eclipses will be very difficult at a 10^{-4-5} level
- Gluing spectral pieces together for transits will be impossible at a 10^{-4-5} level

Both the ELTs and JWST will be extremely powerful in detailed observations of particular aspects of exoplanet atmospheres

EChO will provide the overall spectrum of a planet, and a census of the planet population in general.

Hopefully, all three instruments will be operational in parallel to provide an optimal synergy.