EChO :
The Exoplanet Characterization Observatory

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« Feeding the giants », August 30, 2011

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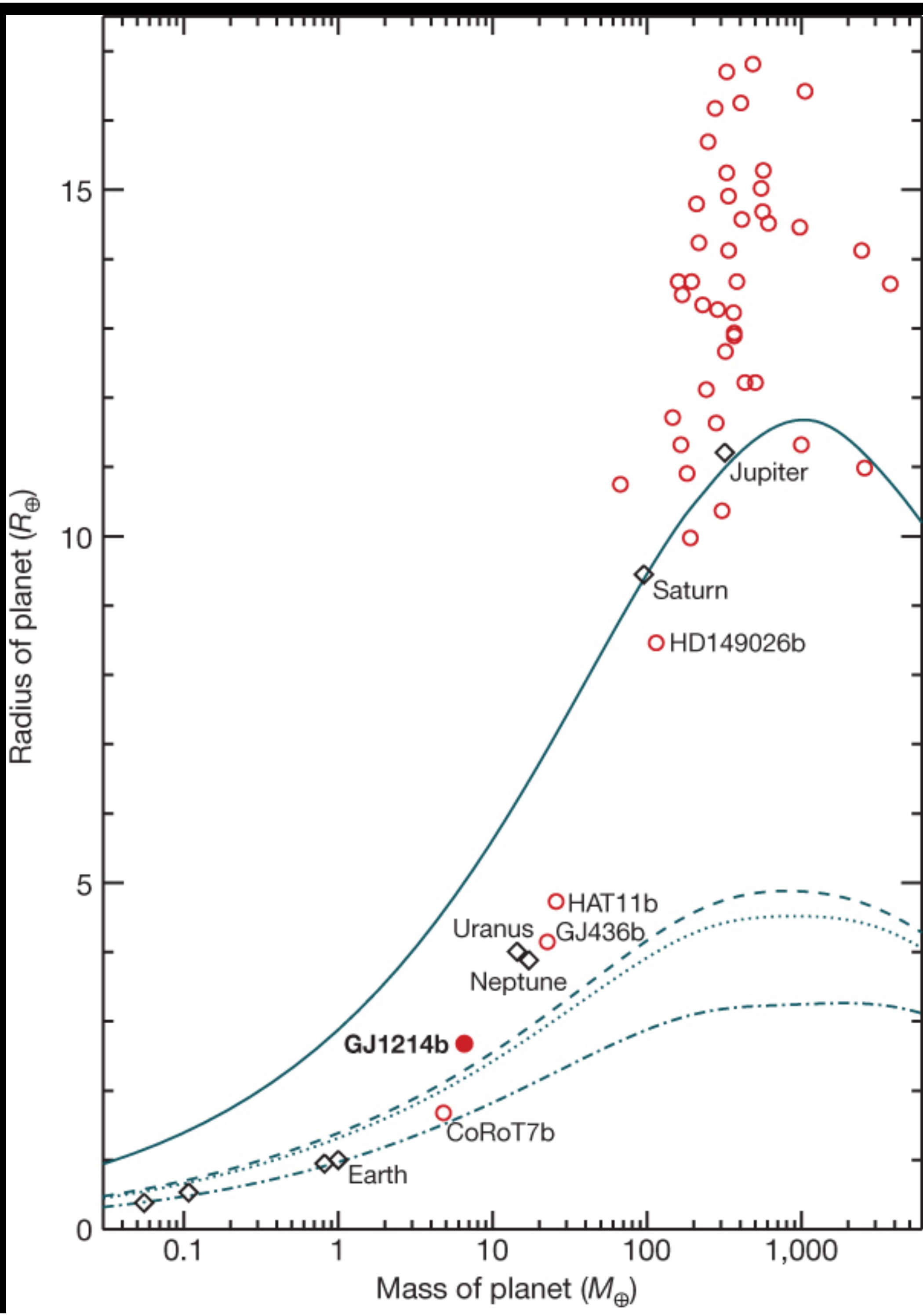
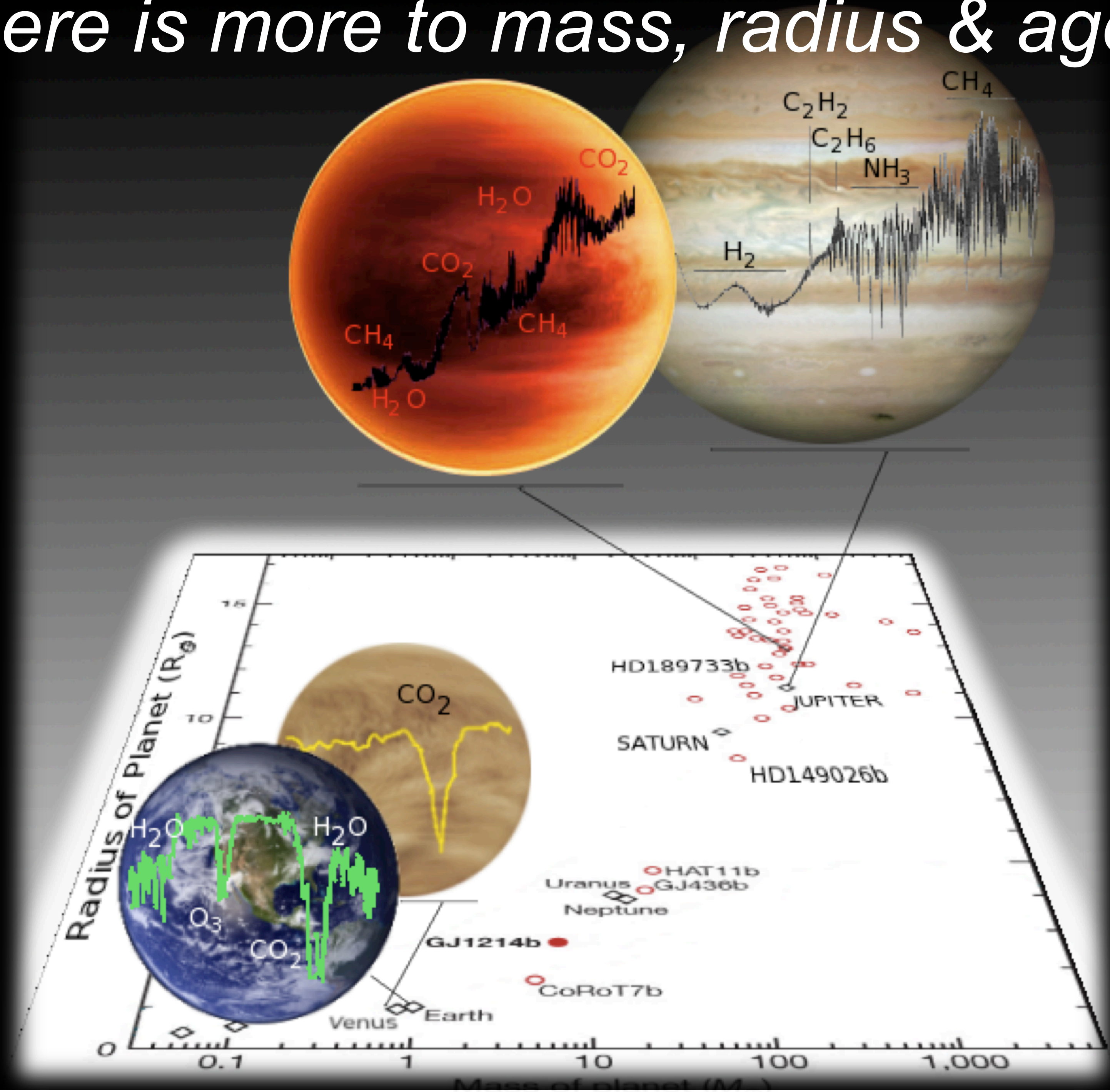


Radius of planet ($R_\oplus$)
Mass of planet ($M_\oplus$)
0
5
10
15
0.1
1
10
100
1,000
Jupiter
Saturn
HD149026b
HAT11b
Uranus
GJ436b
Neptune
GJ1214b
CoRoT7b
Earth

There is more to mass, radius & age…



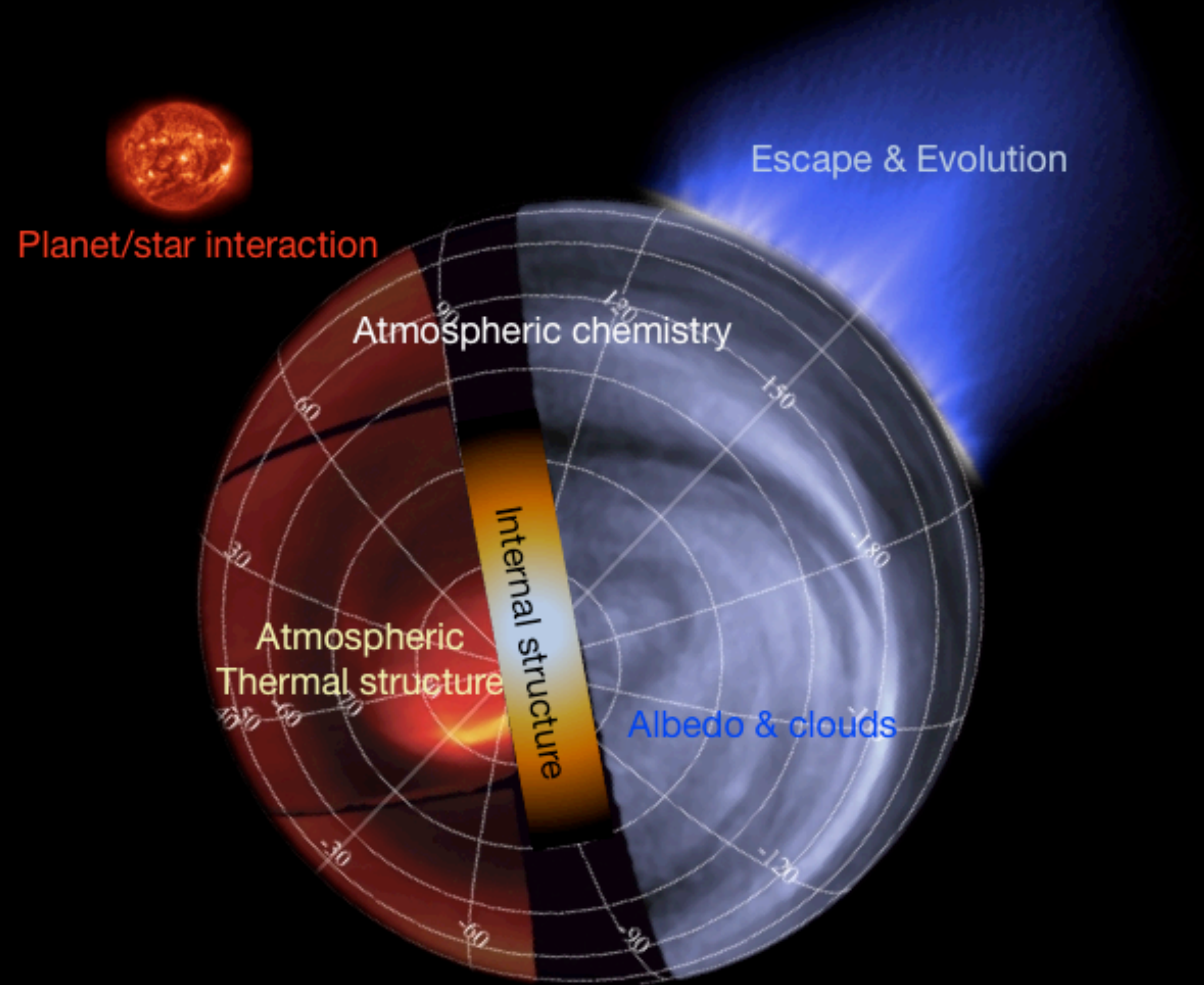
The key challenge is moving on from simple discovery, to characterisation:

- *What are these planets actually like?*

(atmospheric composition? thermal properties?)

- *Why are they as they are?*

For a portfolio of exoplanets of different types (Jupiters, Saturns, Neptunes, Super Earths), from hot to temperate



ECHO

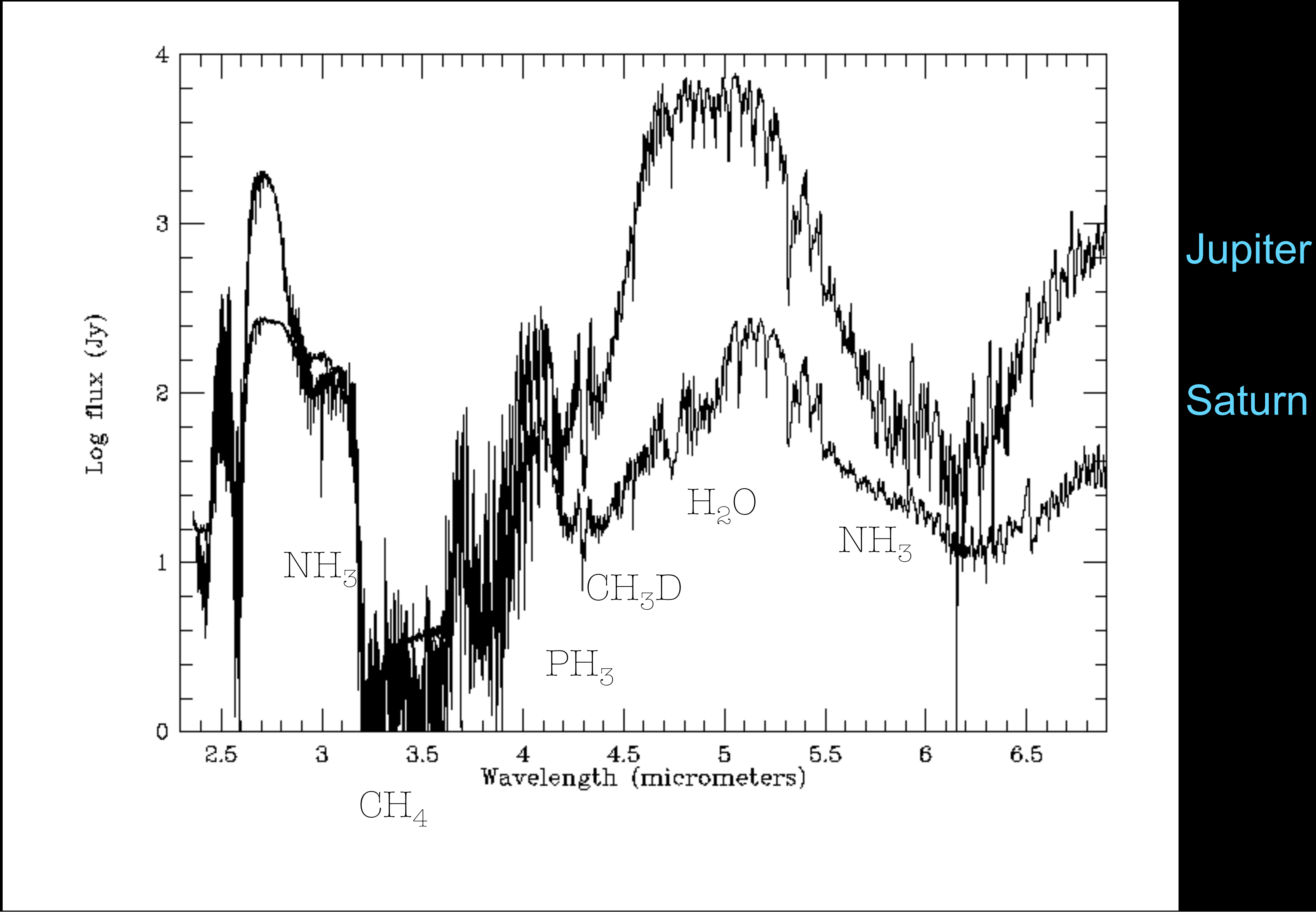
- Spectroscopy of transiting planets

- Phase curves of non-transiting planets

A 1.4m telescope, with spectroscopy 0.4-16 microns, R=300-60
Optimized for stability.
One of the 4 M class missions pre-selected by ESA for the M3 slot
ESA CDF study (June 2011). Next selection process 2013

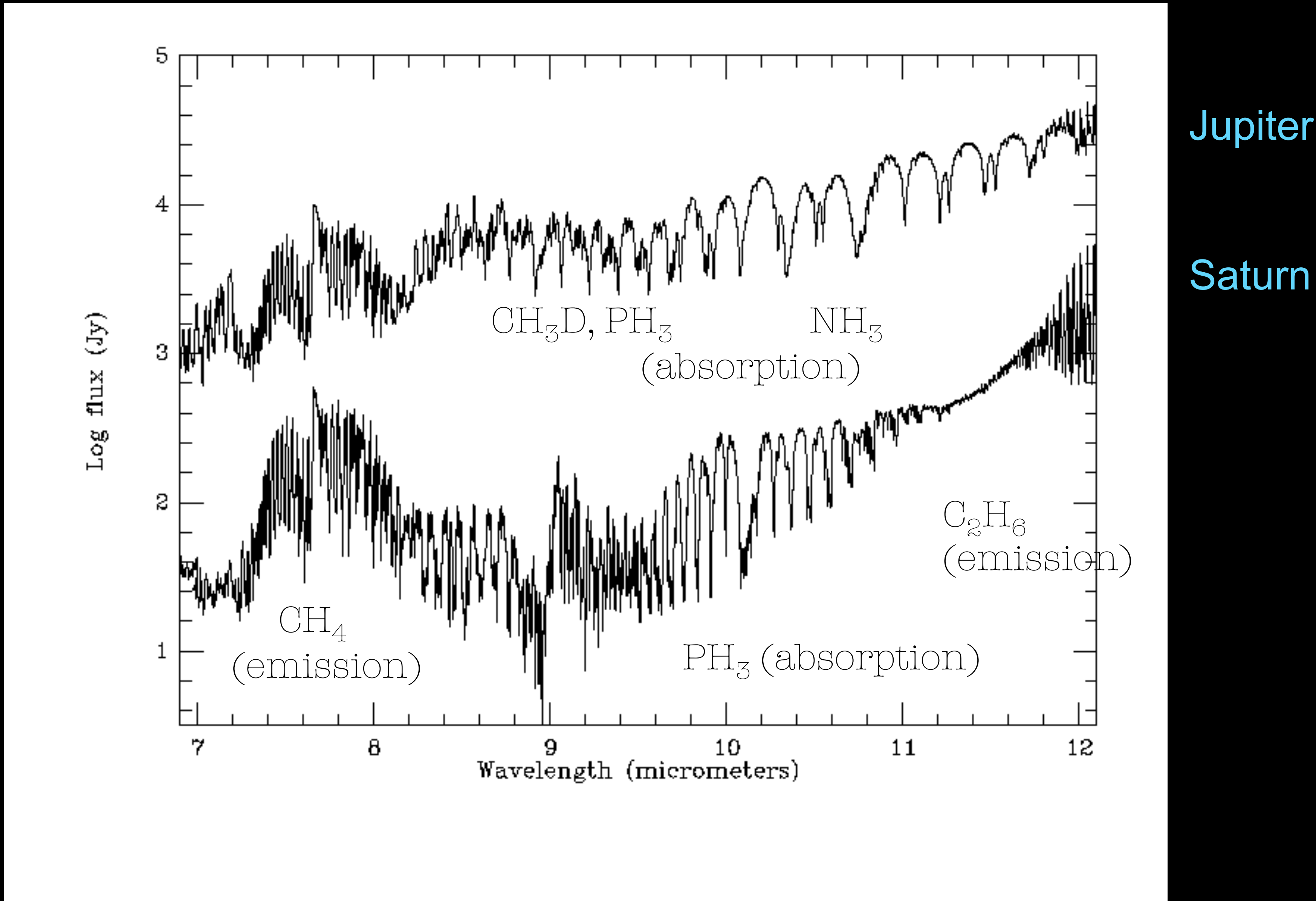
Jupiter & Saturn with ISO-SWS: 2.3-6.8 um

Line identification @ 5 um: R > 200



Jupiter & Saturn with ISO-SWS: 7-12 μm

Line identification : R > 100

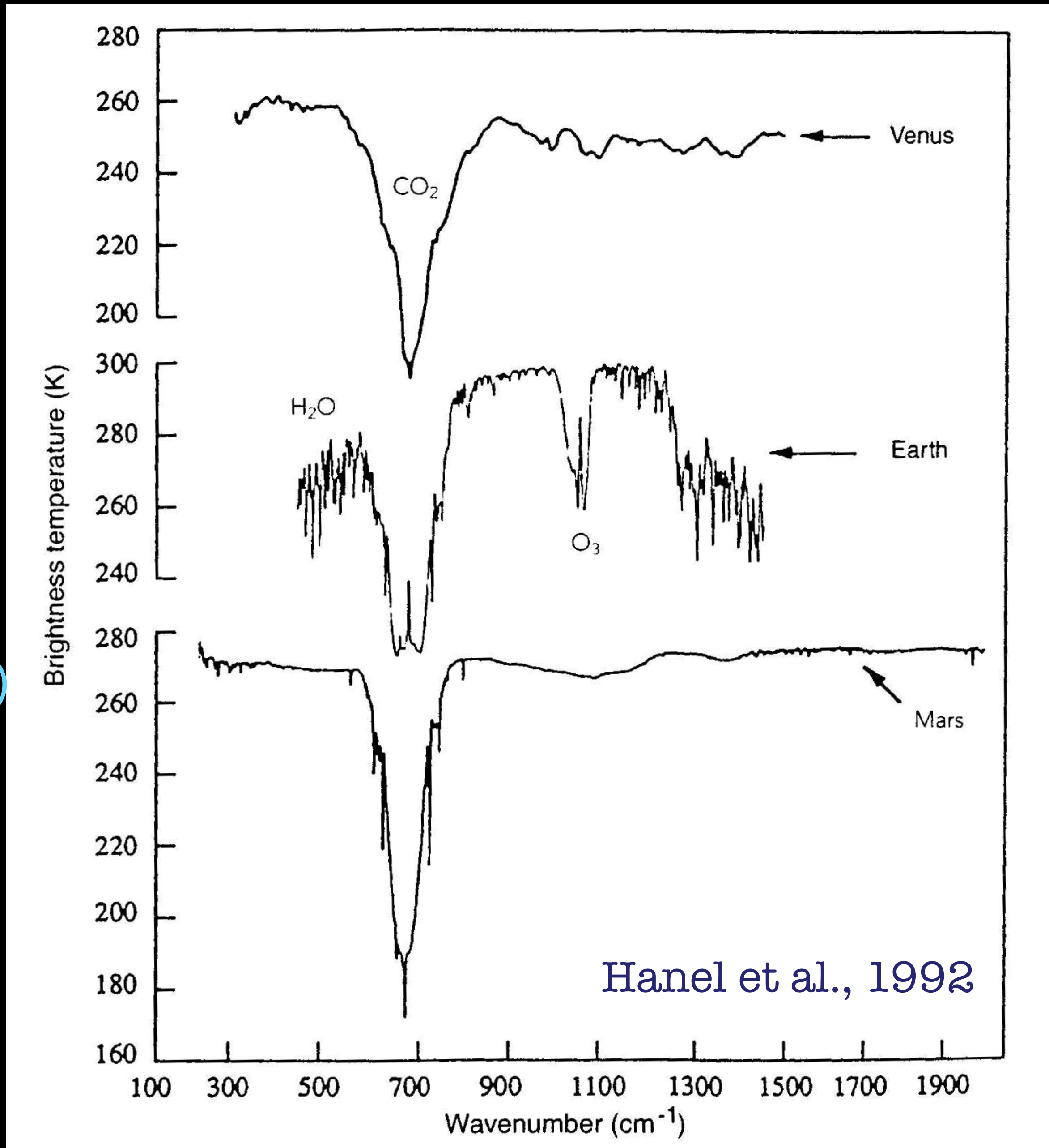


Telluric planets

Resolution :

CO_2
$\Delta\lambda$ = 3 mm; (R = 3)

O_3
$\Delta\lambda$ = 1 mm; (R = 10)



Venus

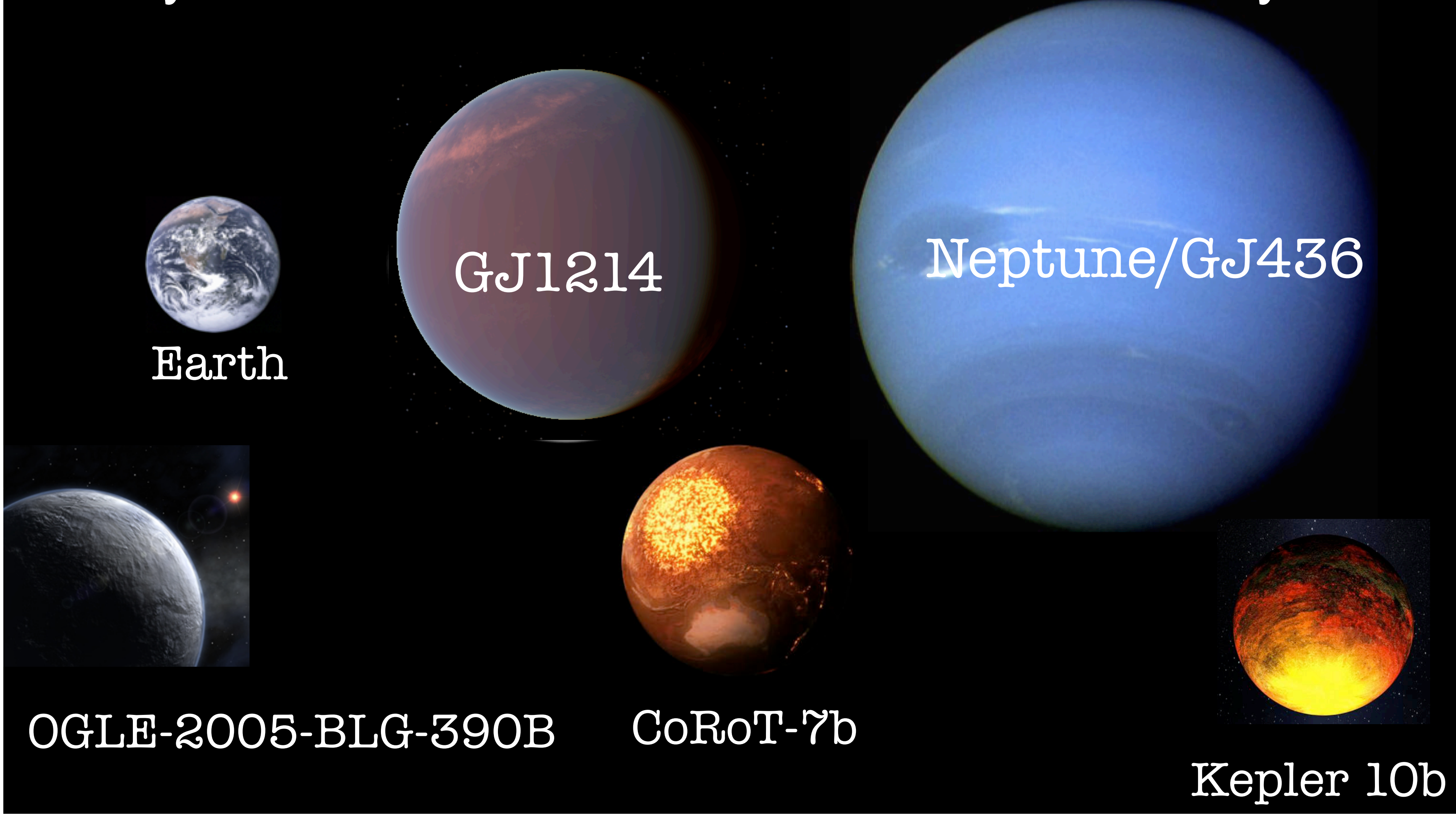
Earth

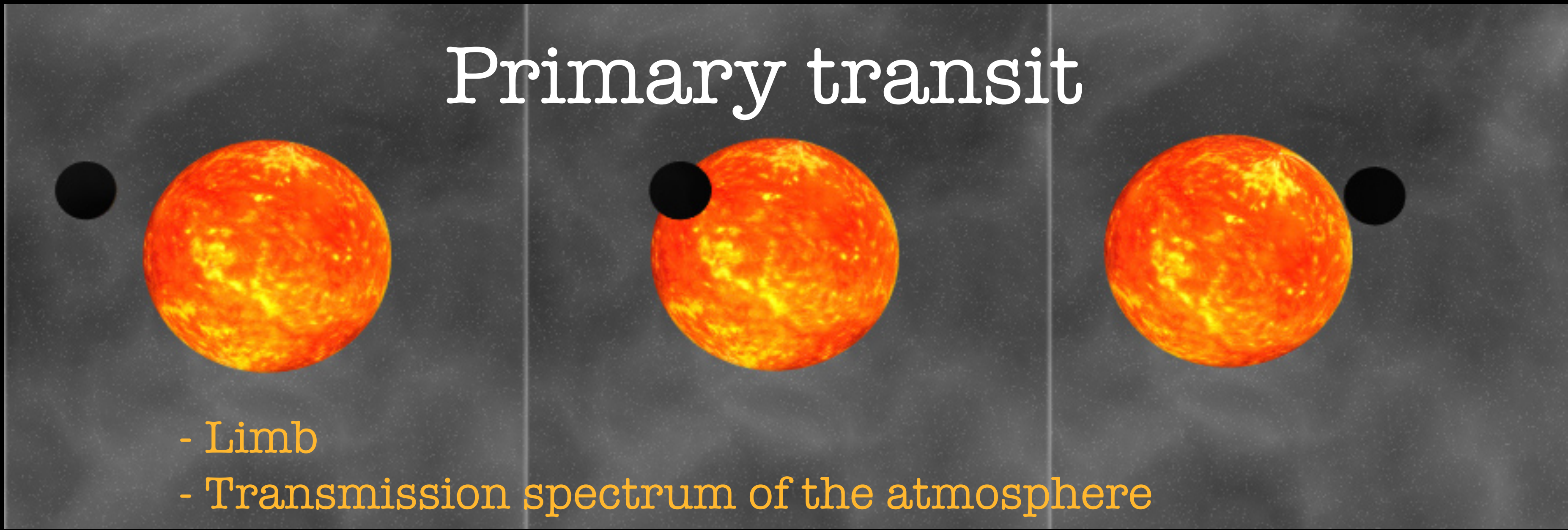
Mars

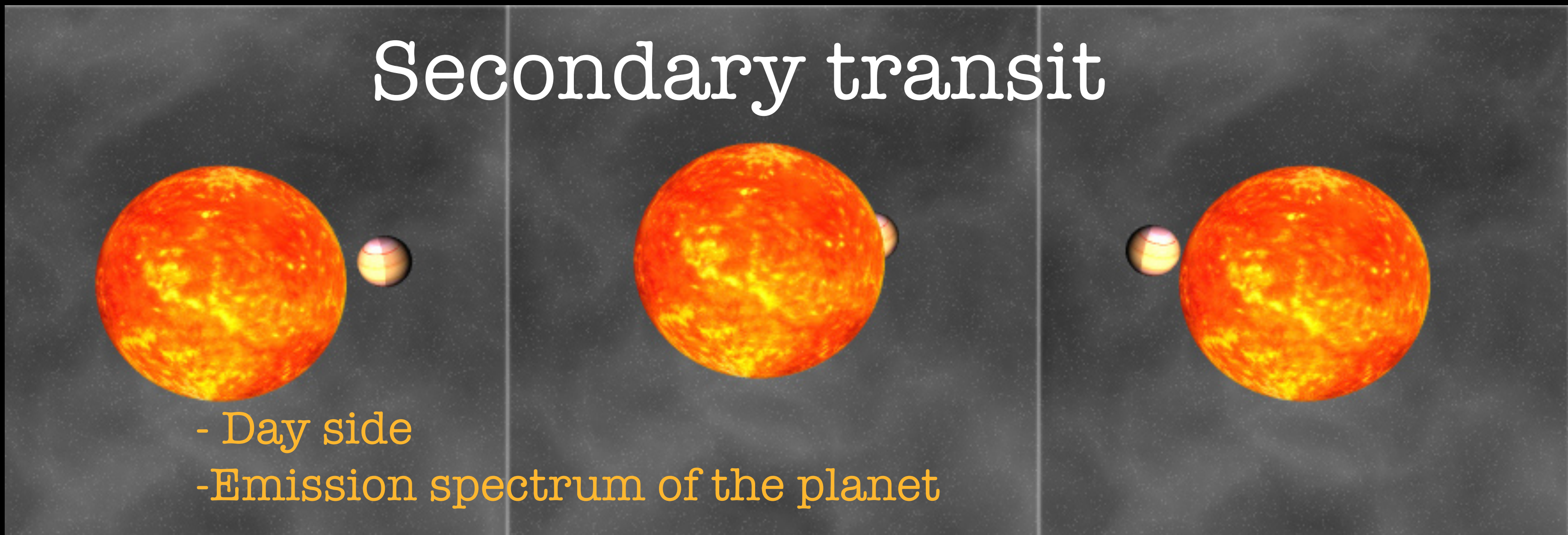
Using the new class of planets with masses between the Earth mass and the 10 Earth masses

–“Super-Earths”–

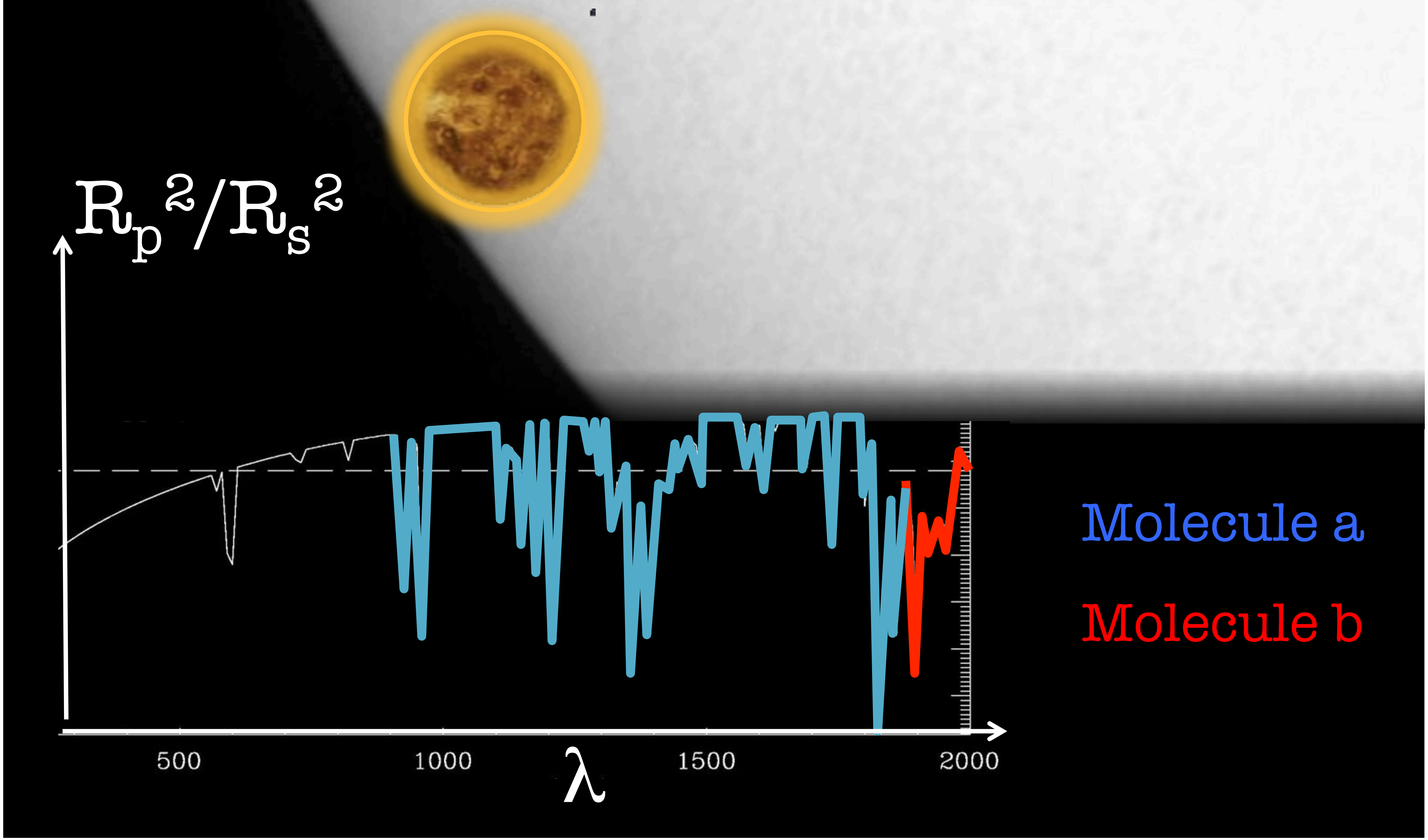
They are common but absent from our Solar System



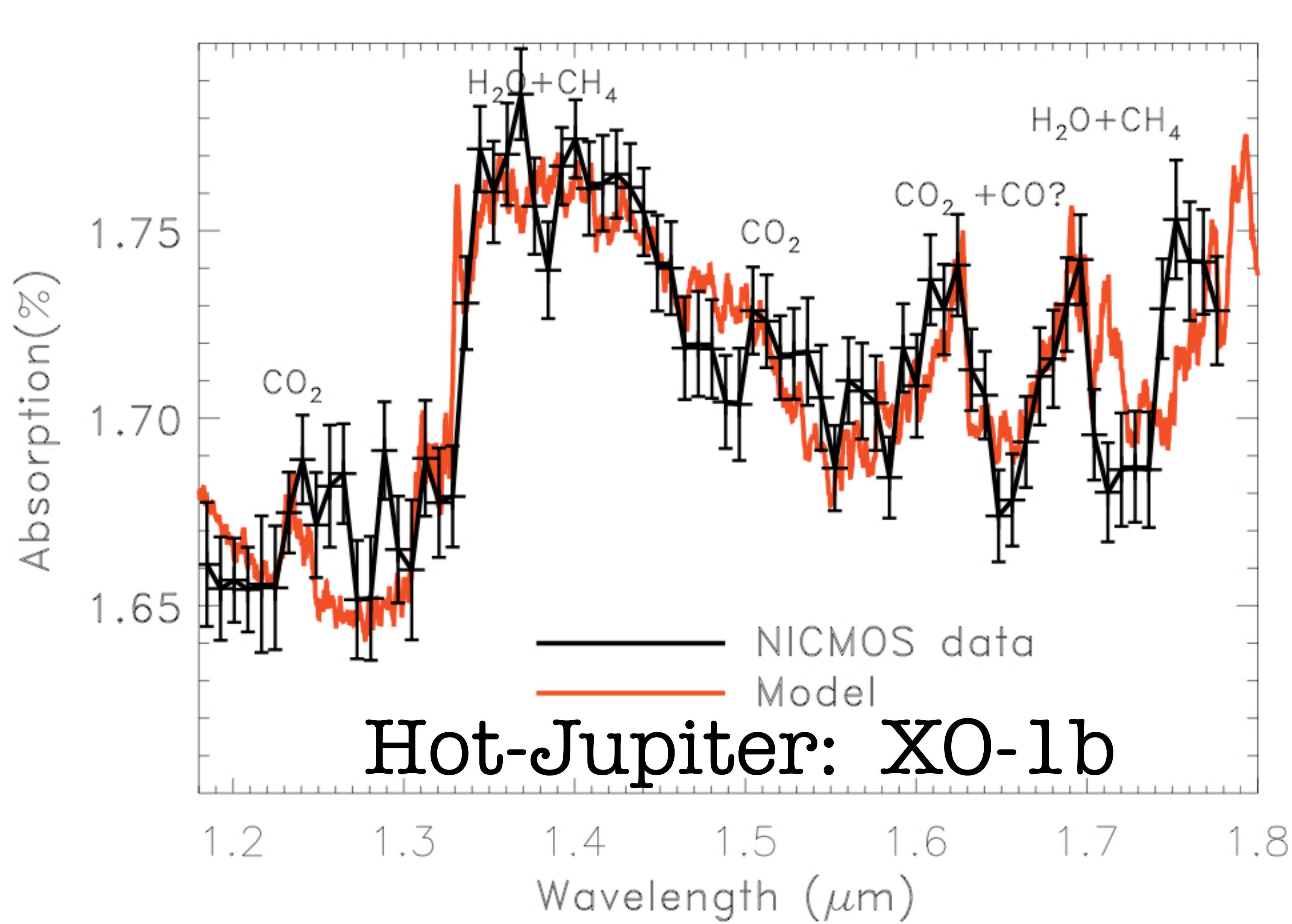

Primary transit
- Limb
- Transmission spectrum of the atmosphere


Secondary transit
- Day side
-Emission spectrum of the planet

Spectral signature of a transiting planet

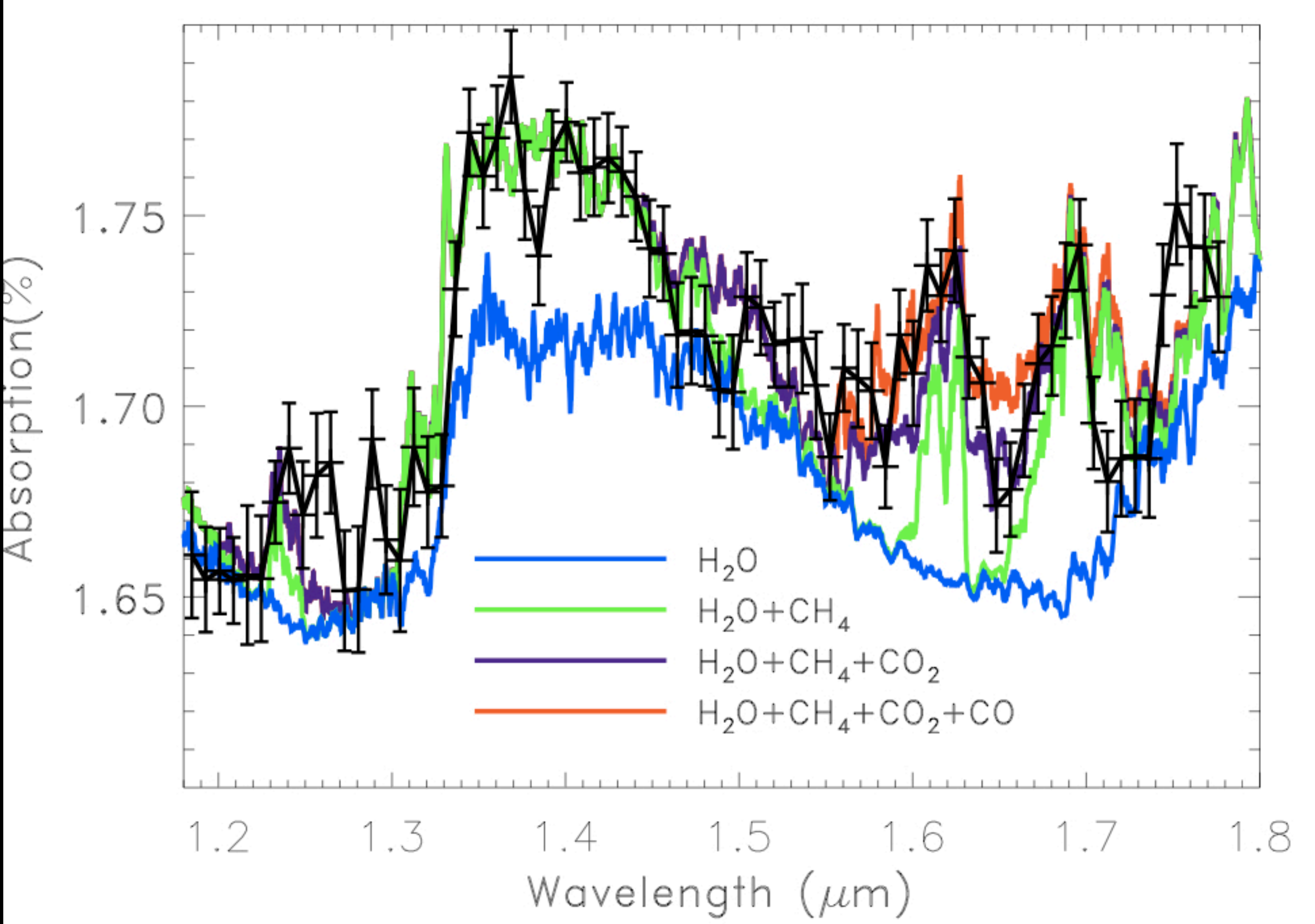


Hubble: transit spectroscopy



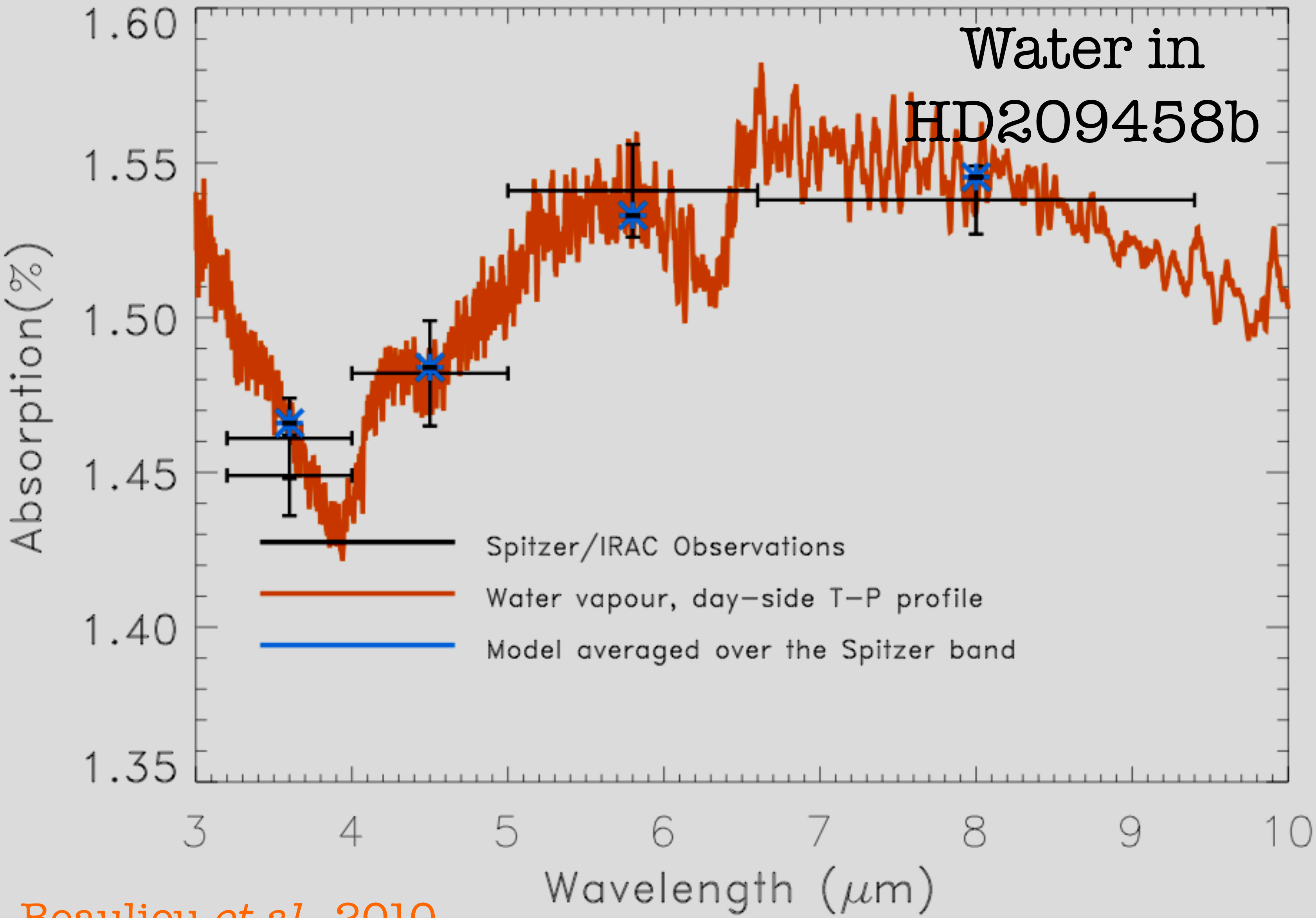
Tinetti, *et al.*, 2010

NICMOS: transmission spectroscopy



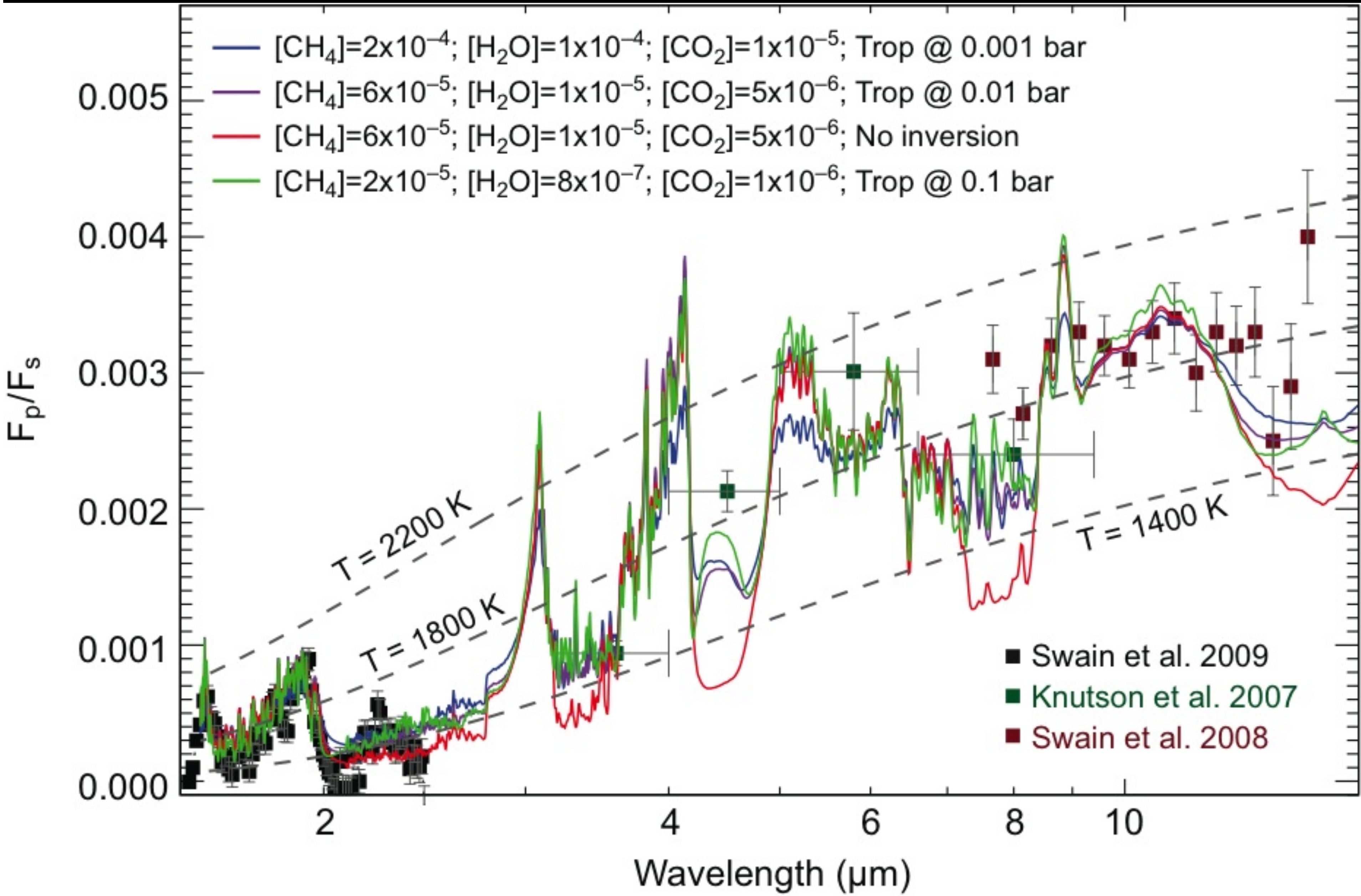
Tinetti, *et al.*, 2010

IR: transmission band-photometry



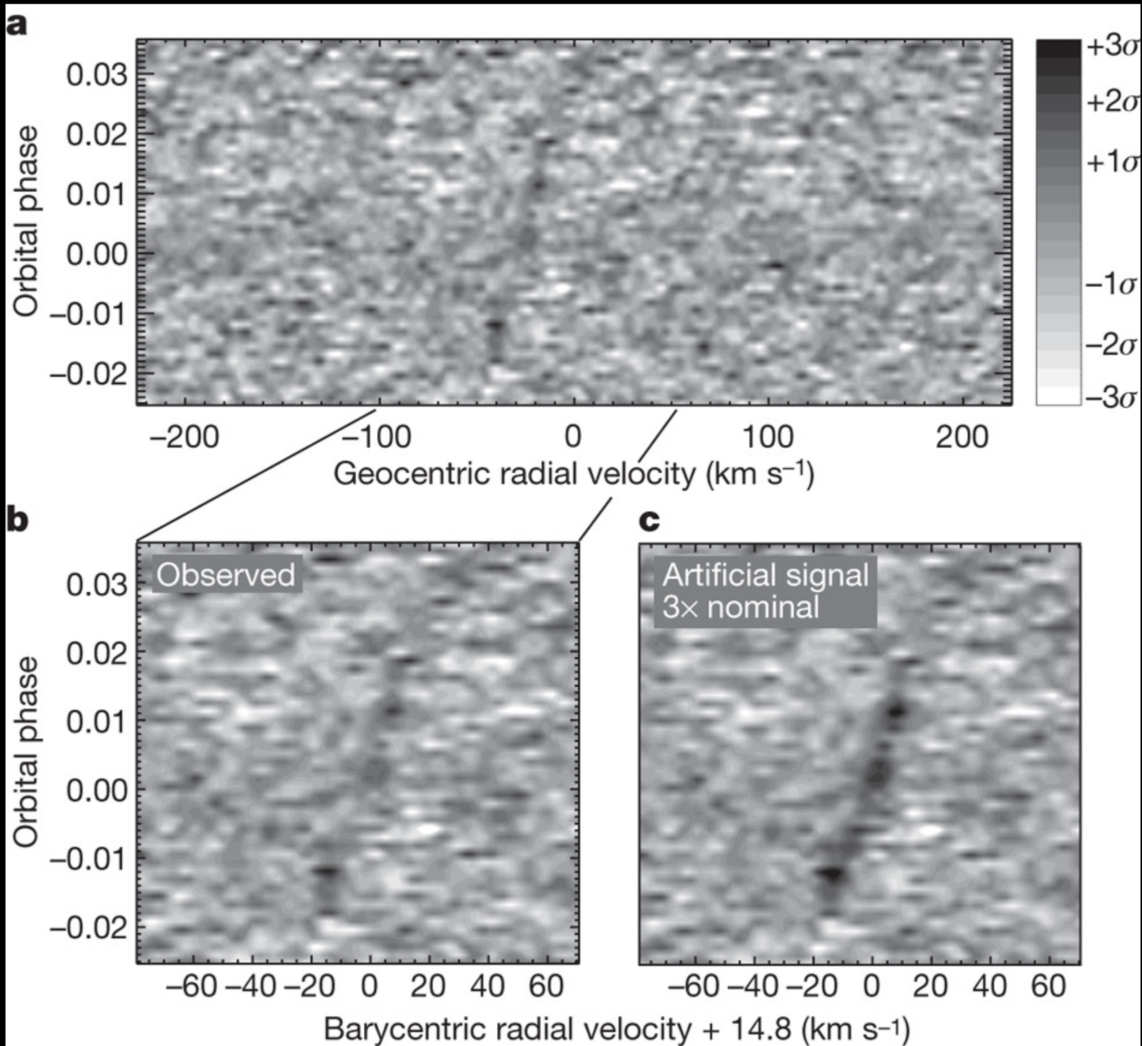
Beaulieu *et al.*, 2010

HD 209458b dayside



Swain, *et al.*, 2009;

CO detection with VLT-Crires

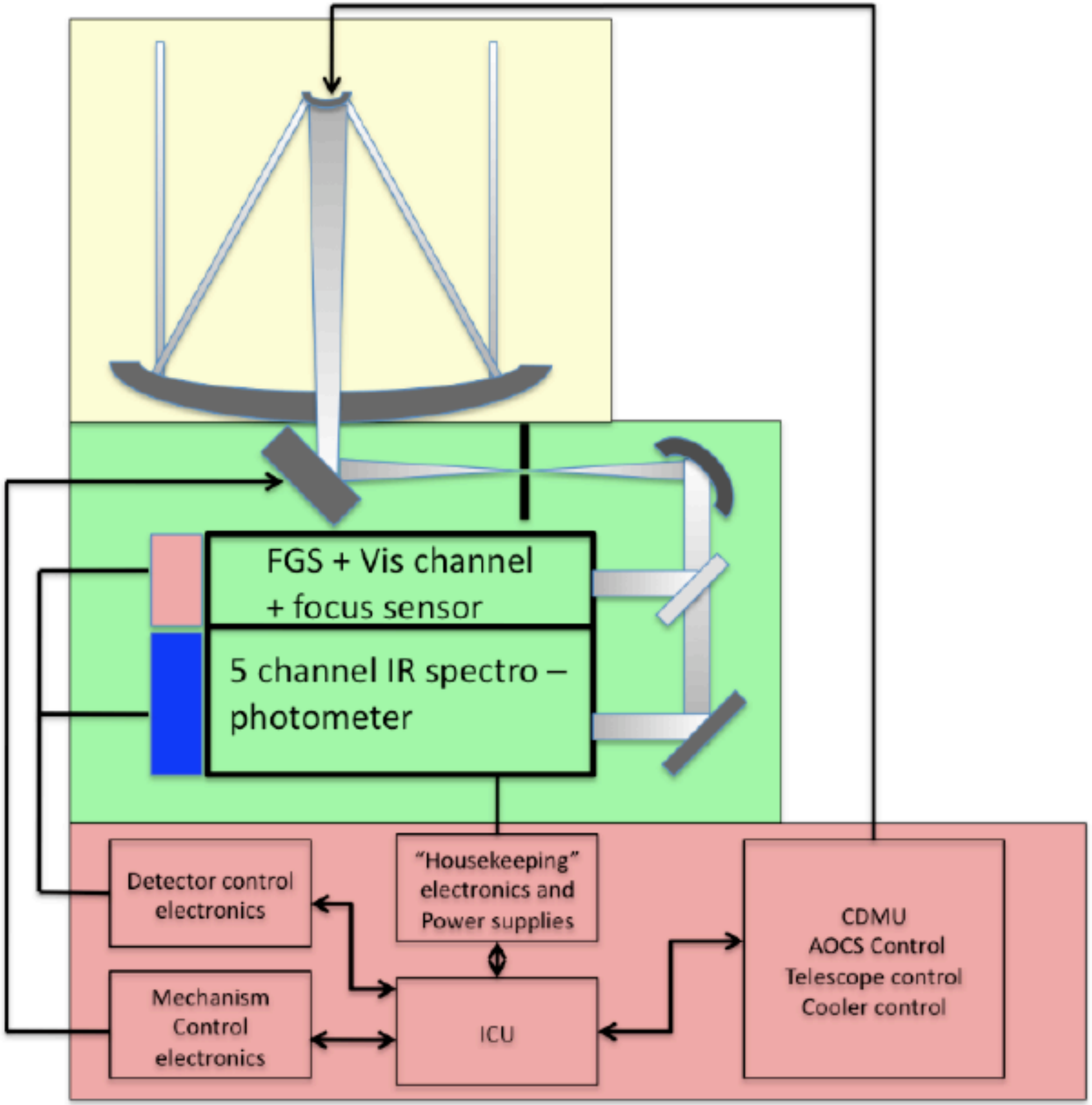


A 2 kms^{-1} wind from day side to night side

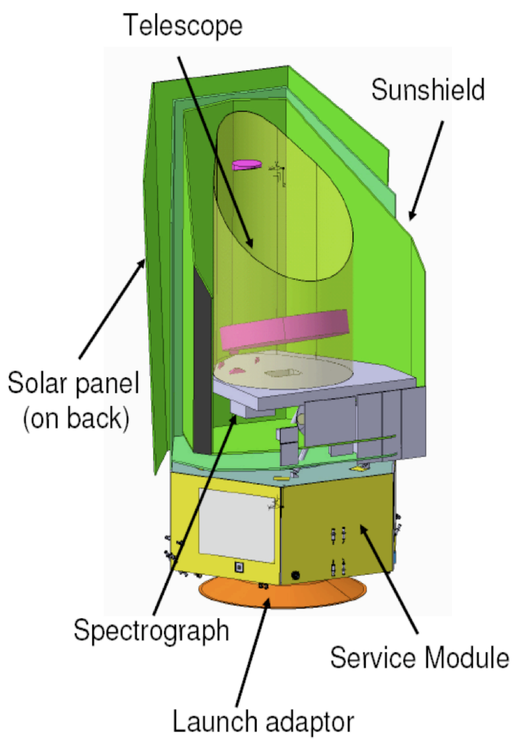
Mixing ratio of CO 1-3 10^{-3}

Snellen *et al.*, Nature, 2010

EChO: 1.4m class telescope in L2
Spectroscopy 0.4-16 microns R=300-60



50 K
45 K
30 K
T amb



Target molecules

	0.4-1 μm	1-5 μm	5-11 μm	11-16 μm
R, baseline	500	300	300	20
R, desired	500	300	300	300
Species				
*H_2O	0.51, 0.57, 0.65, 0.72, 0.82, 0.94	1.13, 1.38, 1.9, **2.69**	6.2	continuum
*CO_2	-	1.21, 1.57, 1.6, 2.03, **4.25**	-	**15.0**
C_2H_2	-	1.52, **3.0**	7.53	**13.7**
HCN	-	**3.0**	-	**14.0**
C_2H_6	-	3.4	-	**12.1**
O_3	0.45-0.75 (the Chappuis band)	4.7	9.1, **9.6**	14.3
HDO	-	2.7,3.67	7.13	-
*CO	-	1.57, 2.35, **4.7**	-	-
O_2	0.58, 0.69, 0.76, 1.27	-	-	-
NH_3	0.55, 0.65, 0.93	1.5, 2, 2.25, 2.9, **3.0**	6.1, **10.5**	-
PH_3	-	4.3	8.9, 10.1	-
*CH_4	0.48, 0.57. 0.6, 0.7, 0.79, 0.86,	1.65, 2.2, 2.31, 2.37, **3.3**	6.5, **7.7**	-
CH_3D	?	3.34, **4.5**	6.8, 7.7, **8.6**	-
C_2H_4	-	**3.22**, 3.34	6.9, **10.5**	-
H_2S	-	2.5, 3.8 ...	7	-
SO_2	-	4	**7.3**, 8.8	-
N_2O	-	2.8, 3.9, **4.5**	7.7, 8.5	-
NO_2	-	3.4	**6.2**, 7.7	13.5
H_2	-	2.12	-	-
H_3^+	-	2.0, 3-4.5	-	-
He	-	1.083	-	-
*Na	0.589	1.2	-	-
*K	0.76	-	-	-
TiO	0.4-1	1-3.5	-	-
VO	0.4-1	1-2.5	-	-
FeH	0.6-1	1-2	-	-
TiH	0.4-1	1-1.6	-	-
Rayleigh	0.4-1	-	-	-
Cloud/haze	yes	possible	silicates, etc.	-
H α	**0.66**			
H β	0.486			
Ca	0.8498, 0.8542, 0.8662		-	-

ECHO channels

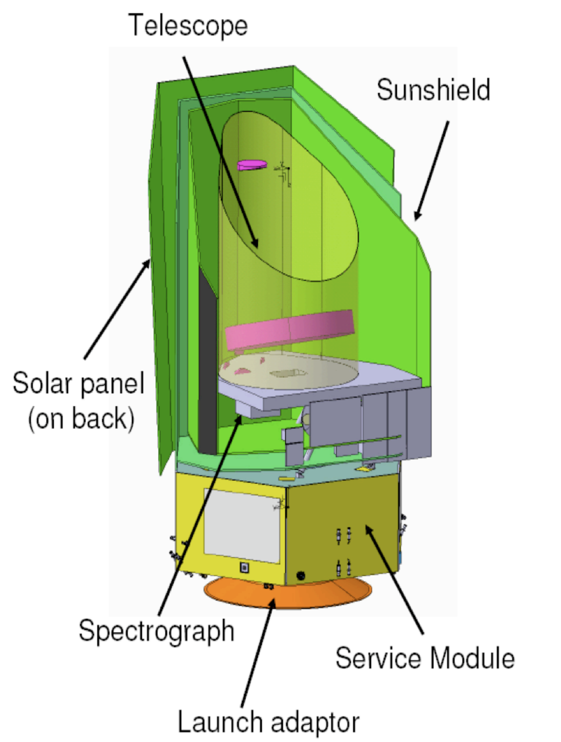
	FGS + FS+ Vis/NIR channel	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5
Bandpass (μm)	0.4 - 1	0.8 – 2.7	2.3 – 5.2	4.8 – 8.5	8.3 – 11	11 - 16
	TELESCOPE					
Diameter	1.2 to1.5 m (larger size to be studied). 1.4 m telescope used in this proposal					
F#	10					
Transmission	98%					
	COLLIMATOR : off-axis parabola					
Focal length	200 mm					
Transmission	99%					
	OBJECTIVES					
Type	Doublet	Doublet	Doublet	Doublet	Doublet	Doublet
Material	PHH 71 LAH 54	F_Silica CaF2	ZnSe Germanium	Silicon AMTIR 1	Silicon AMTIR 1	CdTe CdSe
Focal length	200 mm	150 mm	100 mm	100 mm	100 mm	50 mm
Image F/#	10	7.5	5	5	5	2.5
Transmission	95 %	95 %	95 %	95 %	95 %	95 %
	DISPERSION SYSTEM					
Type	Grating	Grating	Prism	Prism	Prism	Prism
Grating density	111/ mm	64 /mm	N/A	N/A	N/A	N/A
Material	N/A	N/A	CaF2	CaF2	Cleartran	CdTe
Prism angle	N/A	N/A	62 °	47 °	59 °	59 °
Spectral resolution	600	600	600 or better (to be studied)	600	600	20
Transmission	60 %	40 %	90 %	90 %	90 %	90 %
	DETECTOR					
Type	CCD	HgCdTe SWIR	HgCdTe MWIR	HgCdTe LWIR	HgCdTe LWIR	HgCdTe VLWIR
Pixel size		30 μm	15 μm	30 μm	30 μm	30 μm
Needed pixels	600	650	460	330	182	40
Working temperature		< 110 K	< 80 K	<40 K	< 40 K	30 K
Quantum efficiency		0.5	0.7	0.7	0.7	0.7
Dark current (e-/s/px)		$< 10^{(1)}$	$< 10^{(1)}$	500	500	10000(2)
Readout noise (e-/px/ro)		150	400	1000	1000	1000

EChO:

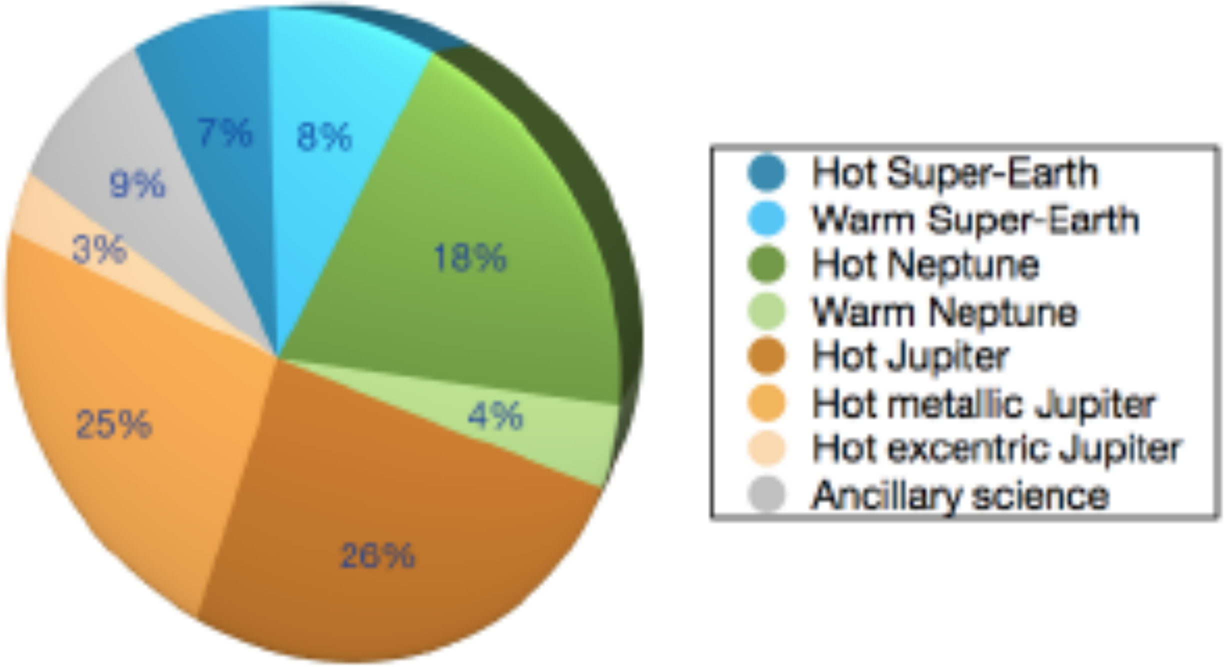
1.4m on axis Cassegrain telescope at F/10
Passively cooled at 50 K
Stability and fiability

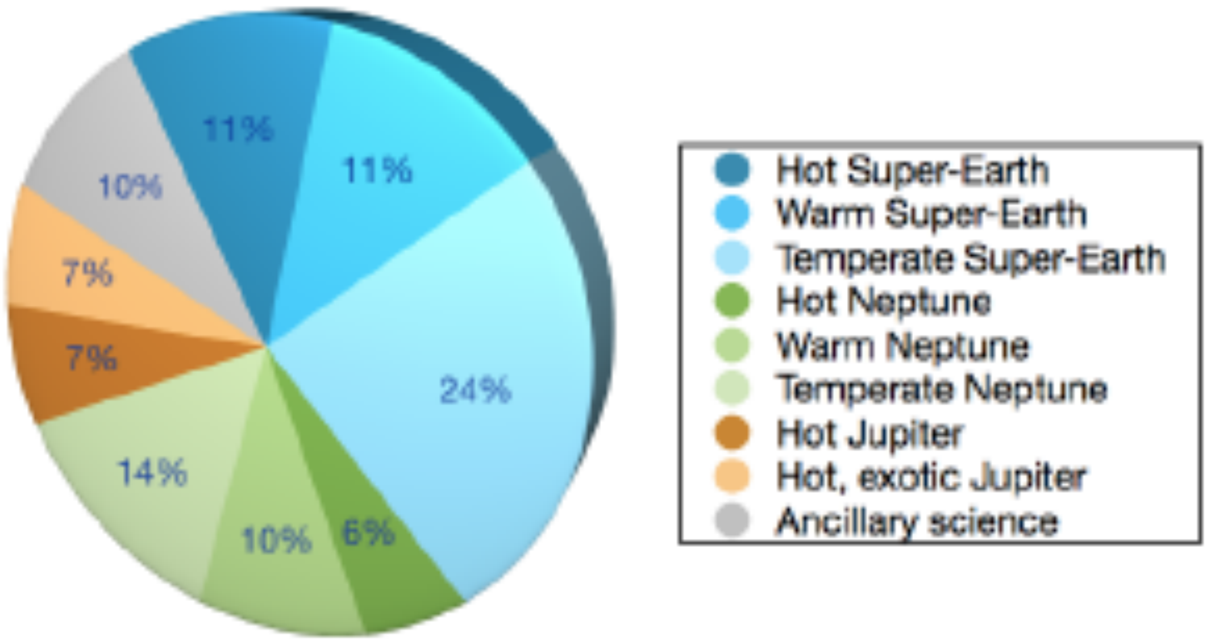
ESA CDF baseline with US detectors :
 (HgCdTe up to 5 µm at 45K, SiAs 5-16 µm at 7K)

On going studies with EU detectors at 30 K.

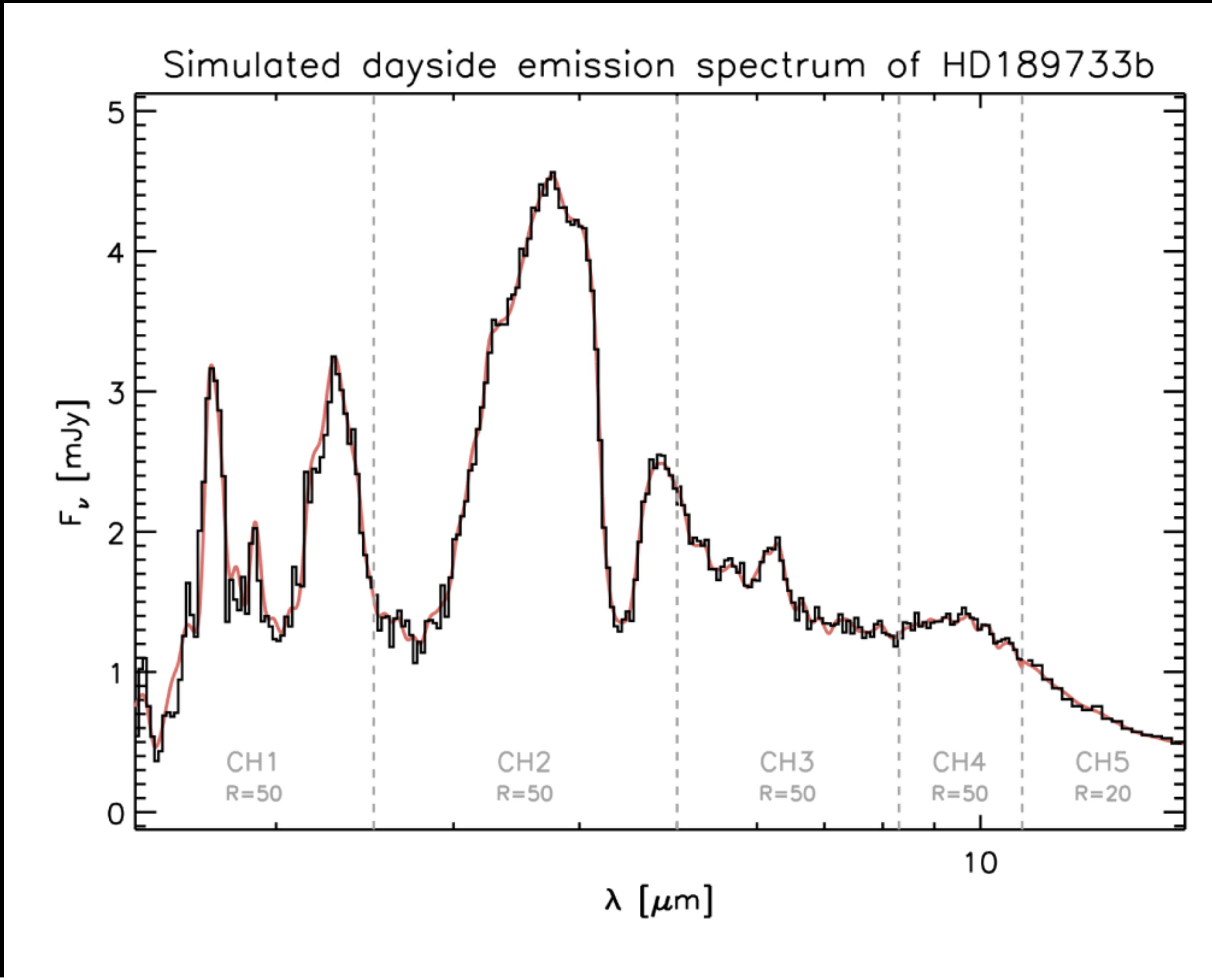


ECHO current Target list



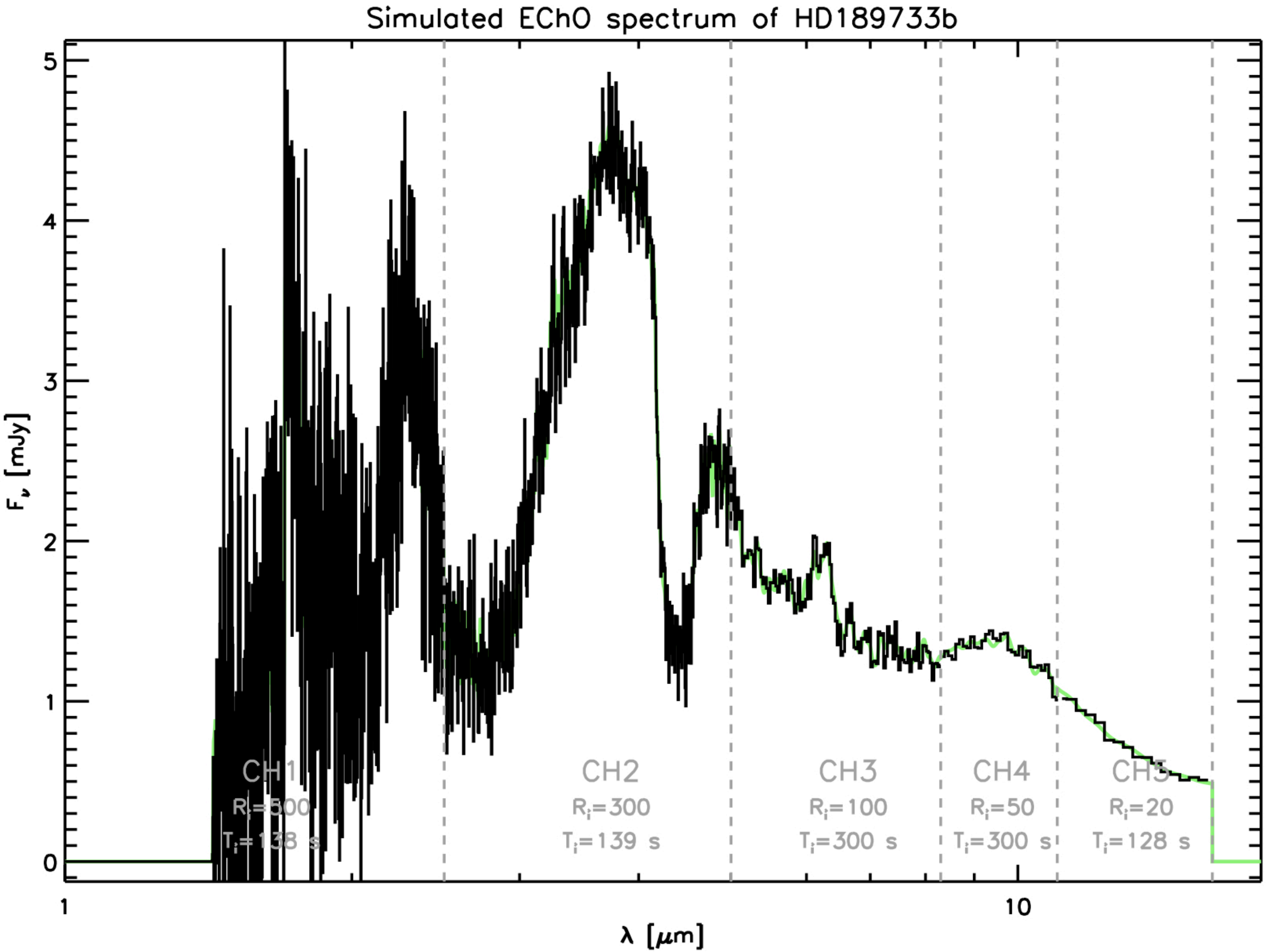


Hot Jupiter HD189733b



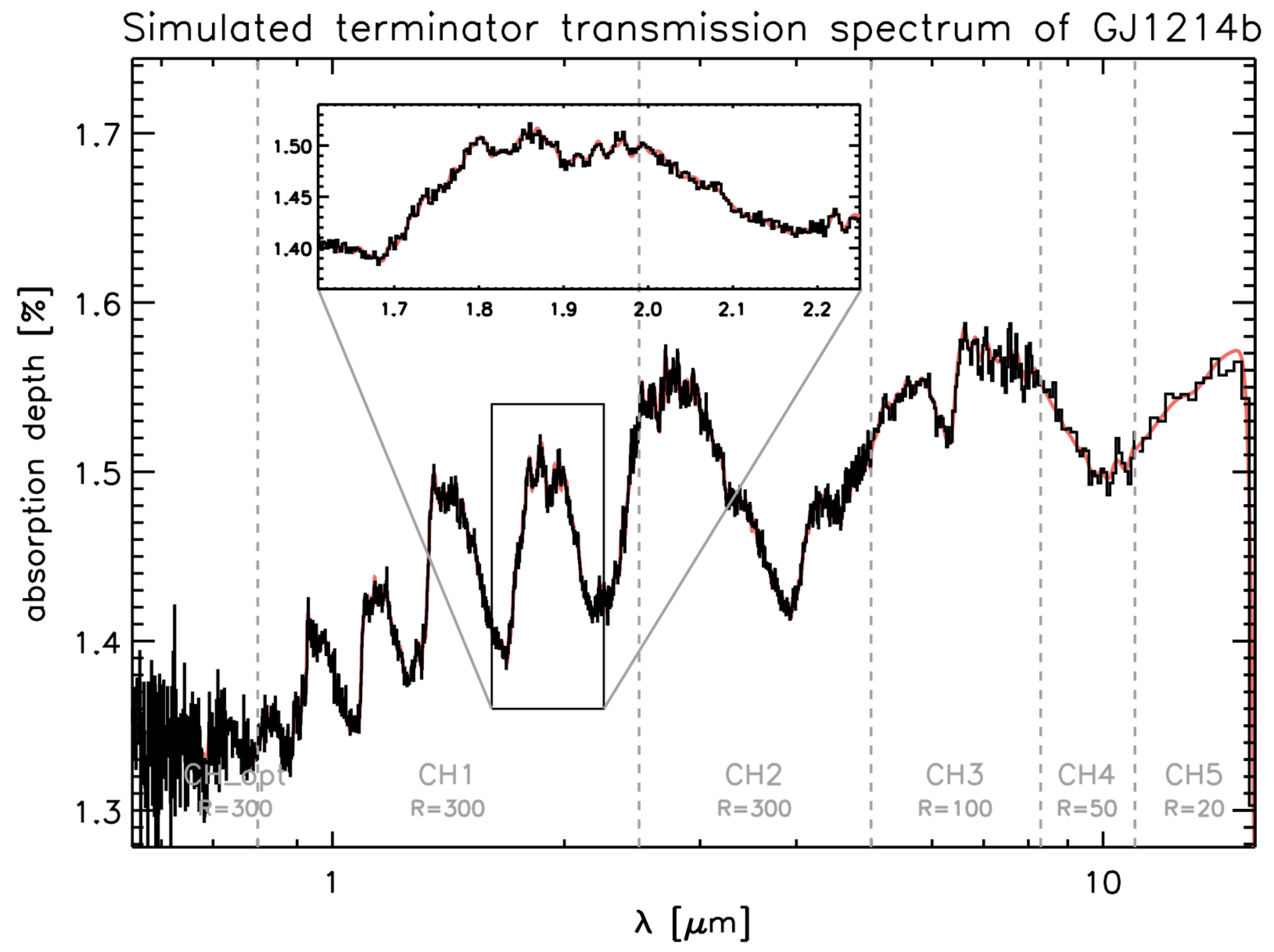
1 transit

8.1-11 μm
Contrast 400
S/N = 15



Simulated EChO spectrum of HD189733b
F_ν [mJy]
λ [μm]
CH1
R_i=500
T_i=138 s
CH2
R_i=300
T_i=139 s
CH3
R_i=100
T_i=300 s
CH4
R_i=50
T_i=300 s
CH5
R_i=20
T_i=128 s

Hot Super Earth GJ1214b



R=300,
300 transits,
21 days of integration
Spread over 1.3 years

Star-type	T (K)	R ($R_\odot$)	contrast ($*10^{-3}$)	Magnitudes in V band 5	6	7	8	9
Secondary eclipse, Resolution 300, SNR 50, averaged over 5-16 µm								
F3	6908	1.56	2	1.5	4	11	34	-
G2	5800	1	3	0.5	1.3	3.3	10	33
K1	4746	0.8	5	0.2	0.6	1.1	3.3	9
Primary eclipse, Resolution 100, SNR 50, averaged over 5-16 µm								
F3	6908	1.56	0.35	15	38	99	270	
G0	6030	1.15	0.65	3.7	9	24	63	
K1	4746	0.8	1.32	0.8	2.2	5	14	

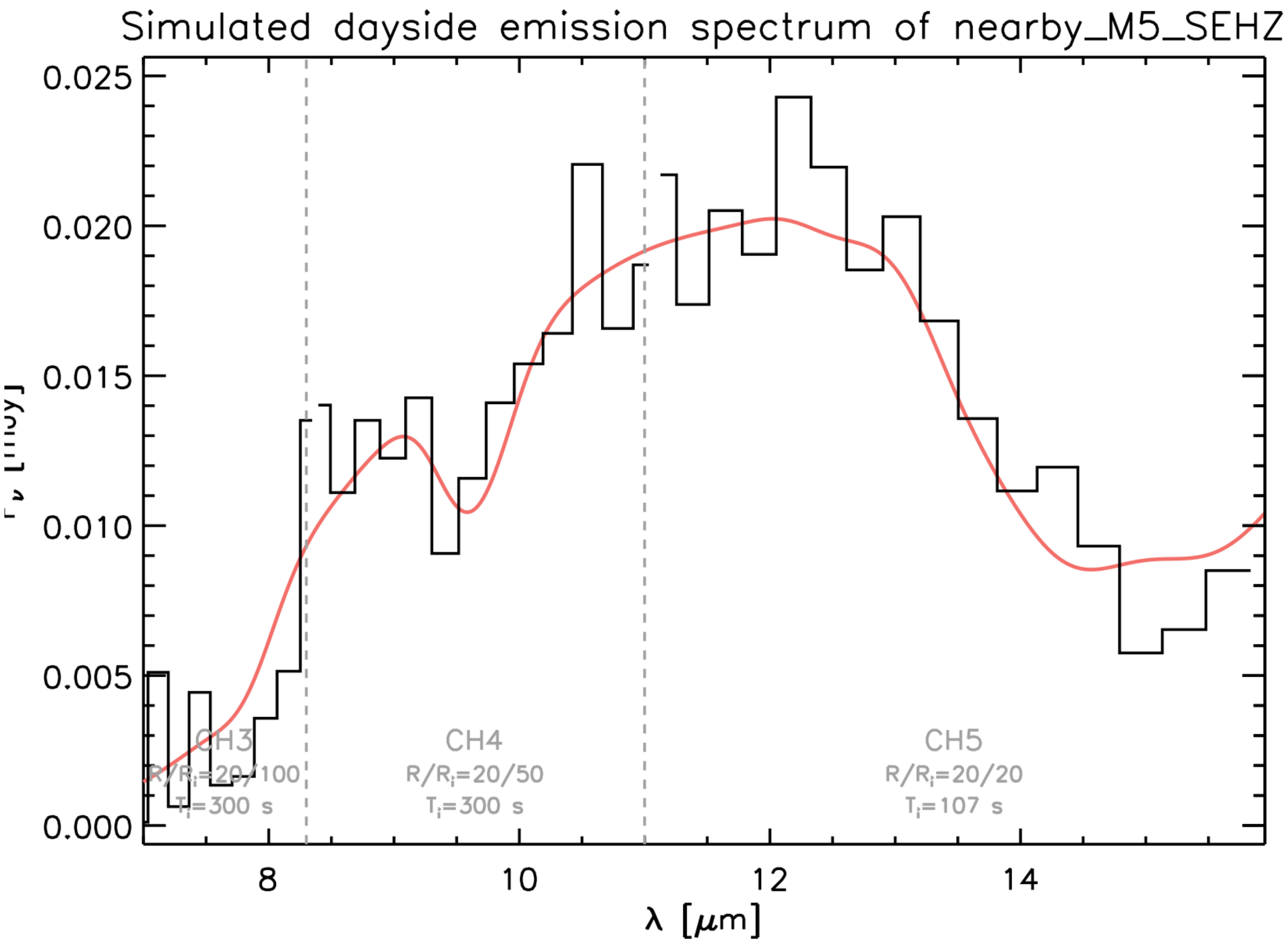
Table 3: Integration times (**in number of transits**) for a hot-Jupiter in primary transit (top) and in secondary eclipse (bottom)

With Resolution 40, SNR 10, 5-16 µm

M-type	T (K)	R ($R_\odot$)	contrast (10^{-4})	Magnitudes in K band 5	6	7	8	9
M1.5V	3582	0.42	1.4	14	36	95	258	-
M3V	3436	0.30	2.8	6	13	34	93	277
M4V	3230	0.19	7.7	1	2	6	18	52
M5V	3055	0.15	13.2	0.5	1	3	8	23

Table 4: Integration times (in number of transits) for a hot (850 K) Super-Earth (1.6 R_{earth}) in secondary transit

Habitable super earth orbiting a M5



80 hours of observing

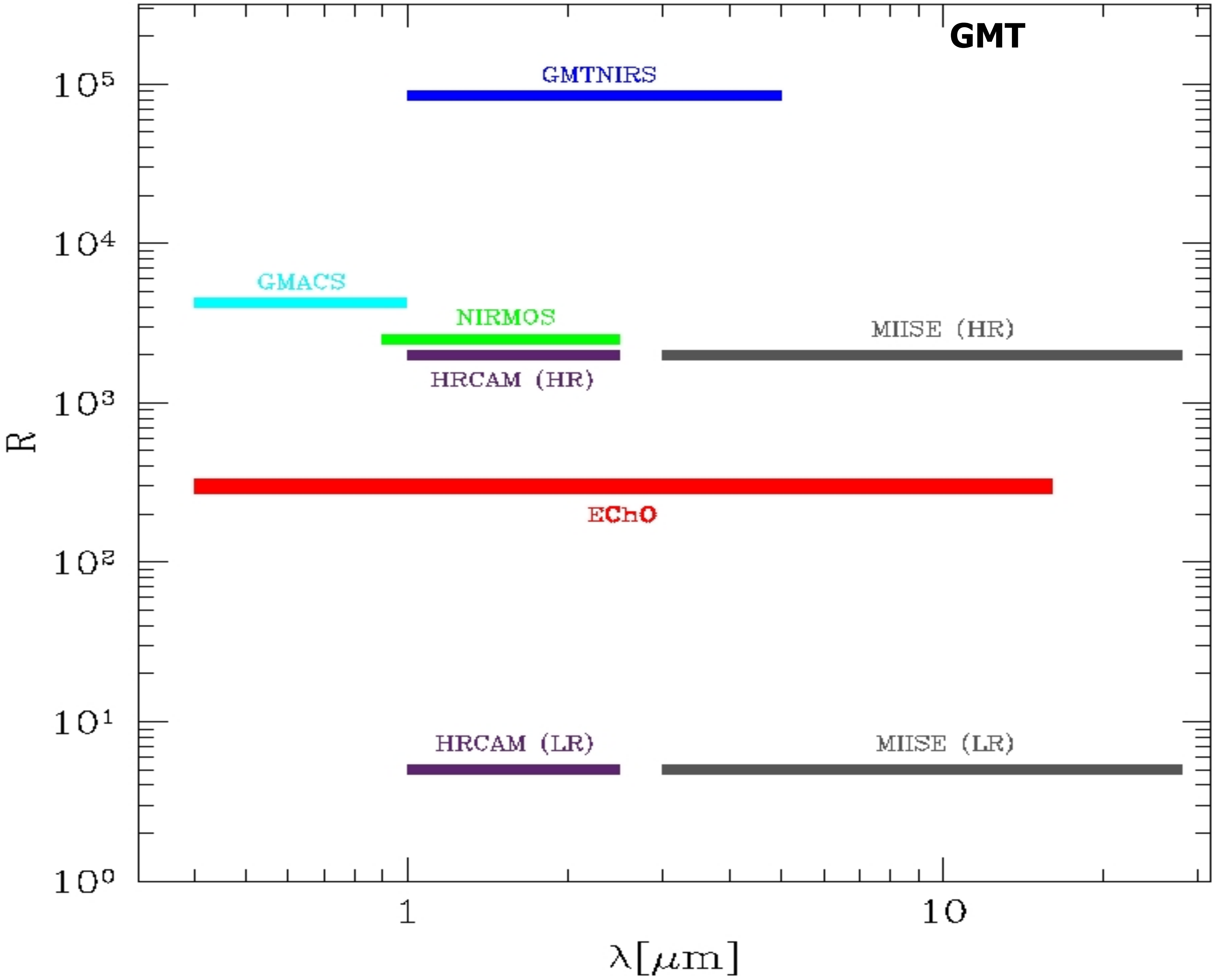
8.1-11 μm
R=20
S/N = 15

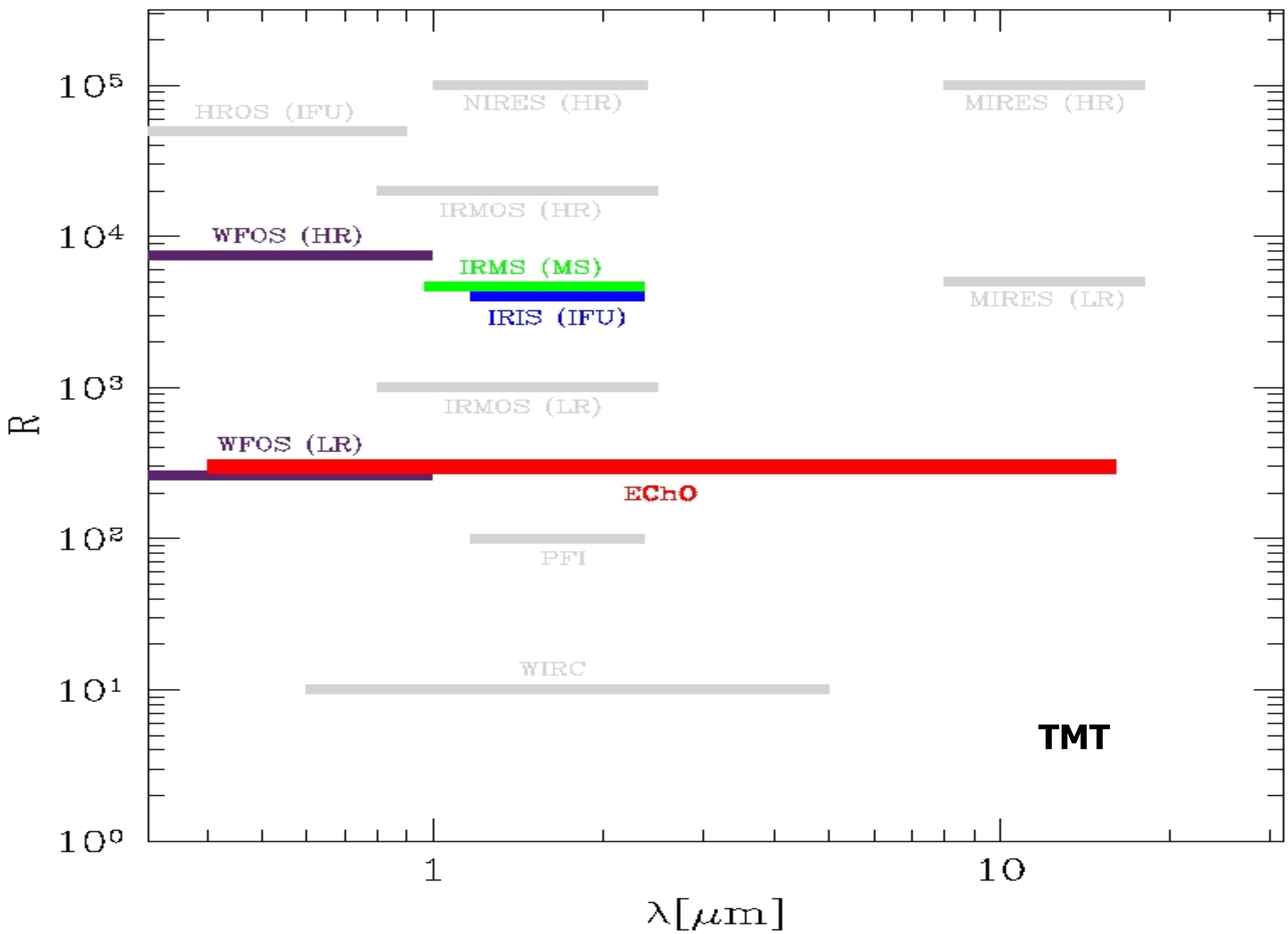
Habitable super earth with ECHO

With Resolution 10, SNR 5, 5-16 μm

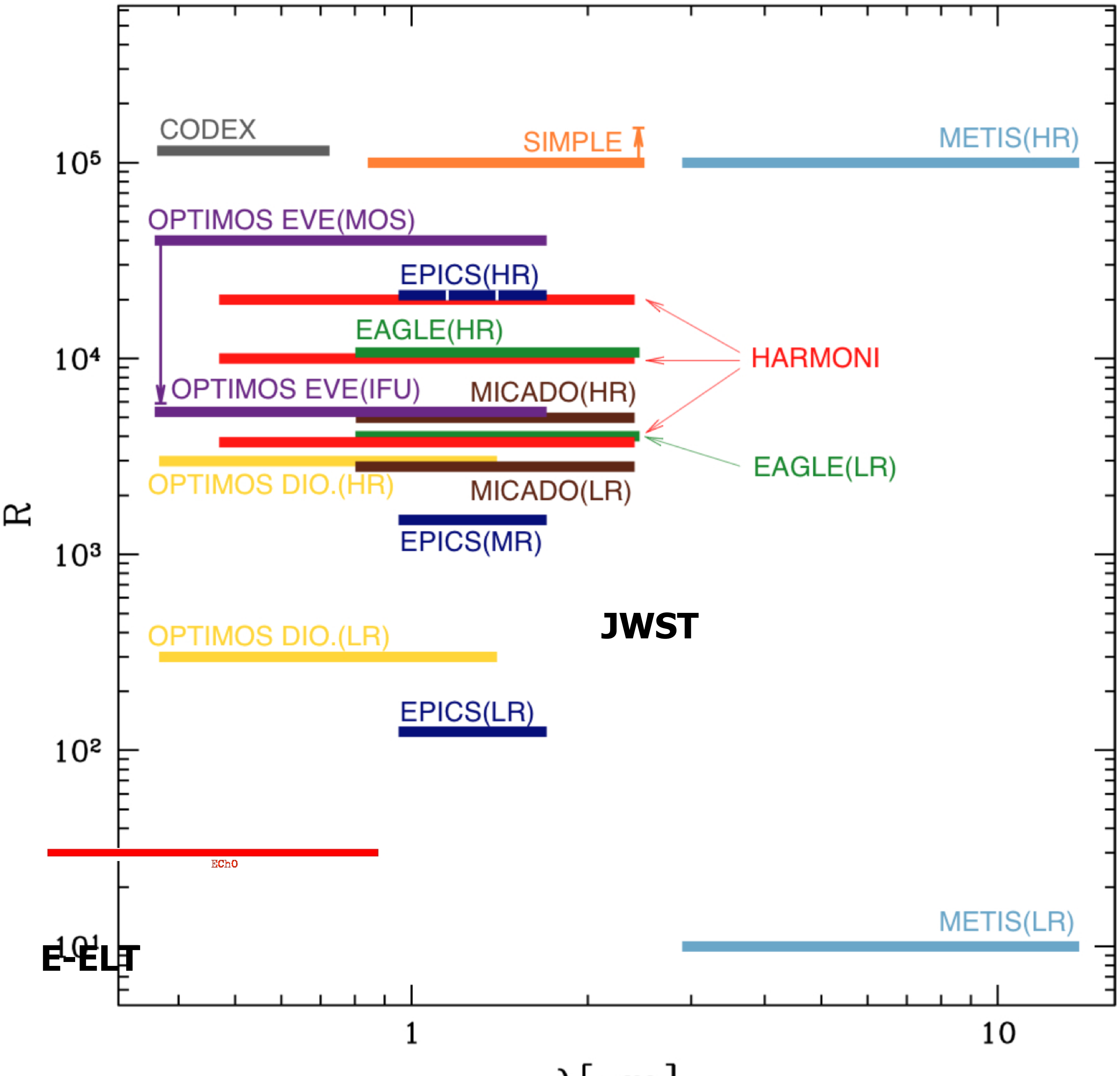
Star type	T (K)	R ($R_\odot$)	Period (days)	contrast (10^{-5})	Magnitudes in K 5	6	7	8	9
M2V	3522	0.38	30.6	0.9	72				
	3475	0.34	26.6	1.2	45	113			
M3V	3436	0.30	23	1.5	32	81			
	3380	0.25	19.3	2	20	52	132		
M4V	3230	0.19	12.7	4		18	46	117	
	3150	0.17	10.7	5.2		12	32	80	208
M5V	3055	0.15	8.7	6.9			19	49	128
	2920	0.13	6.7	9.8			12	29	76

Table 5: Integration times (number of transits) for a habitable-zone (320 K) Super-Earth (1.6 $R_\odot$) in secondary transit


GMT
GMTNIRS
GMACS
NIRMOS
MIISE (HR)
HRCAM (HR)
EChO
HRCAM (LR)
MIISE (LR)
R
10^5
10^4
10^3
10^2
10^1
10^0
1
10
$\lambda[\mu m]$

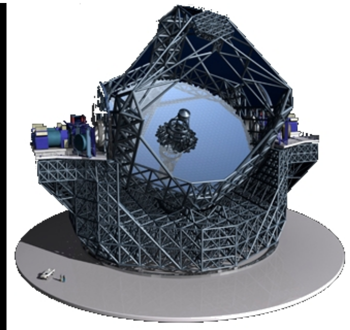


HROS (IFU)
NIRES (HR)
MIRES (HR)
IRMOS (HR)
WFOS (HR)
IRMS (MS)
IRIS (IFU)
MIRES (LR)
IRMOS (LR)
WFOS (LR)
EChO
PFI
WIRC
TMT
R
λ[μm]



CODEX
SIMPLE
METIS(HR)
OPTIMOS EVE(MOS)
EPICS(HR)
EAGLE(HR)
HARMONI
OPTIMOS EVE(IFU)
MICADO(HR)
EAGLE(LR)
OPTIMOS DIO.(HR)
MICADO(LR)
EPICS(MR)
JWST
OPTIMOS DIO.(LR)
EPICS(LR)
EChO
METIS(LR)
E-ELT
R
10^5
10^4
10^3
10^2
10^1
1
10

Synergies with ELTs

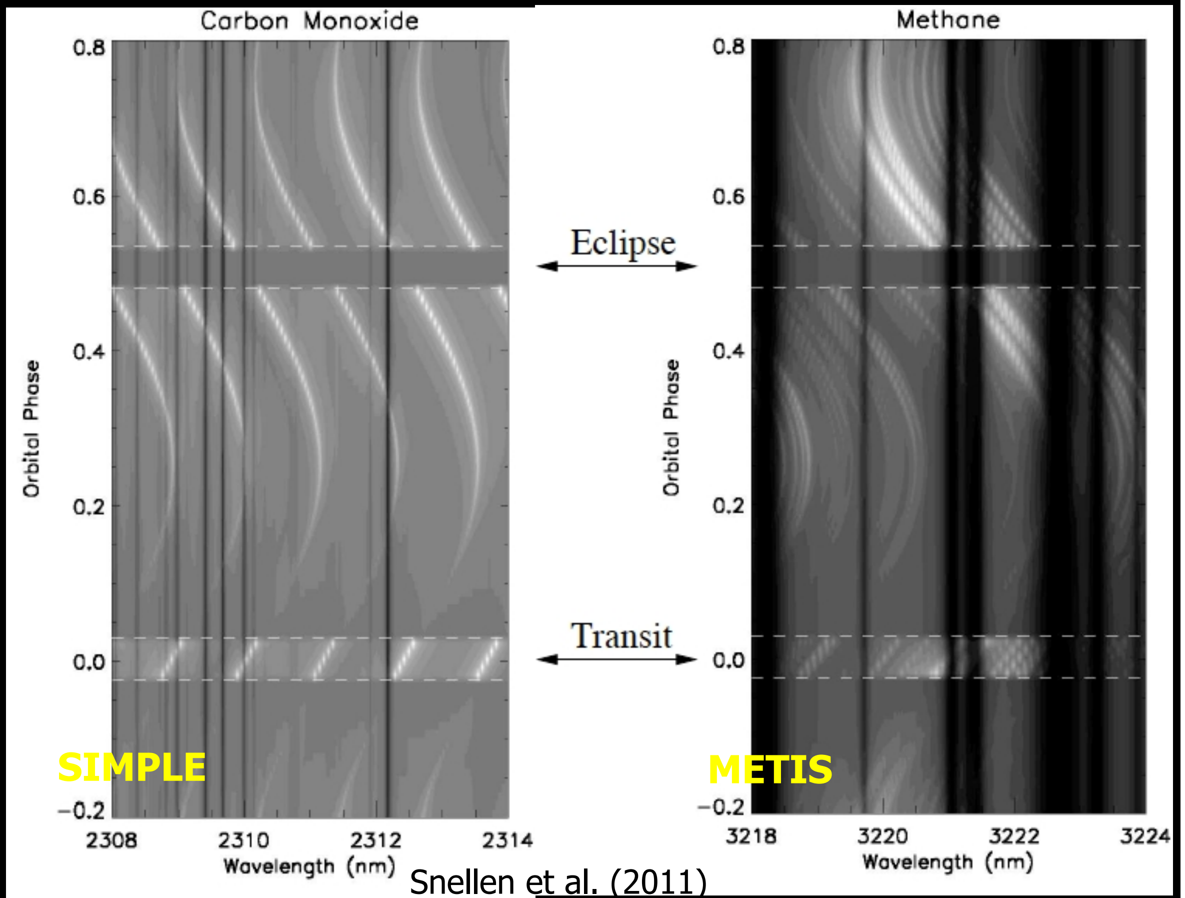


- Combining ECHO and ELTs to measure winds and abundances in some zone of the atmosphere. Similar to Snellen et al. (2010) on smaller and colder planets

E.g. SIMPLE &METIS on E-ELT
Could as Snellen
et al. (2010) for K > 10.

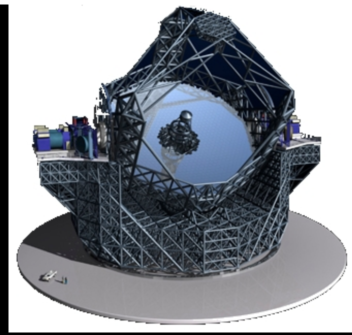
-CO, H_2O, CH_4, …

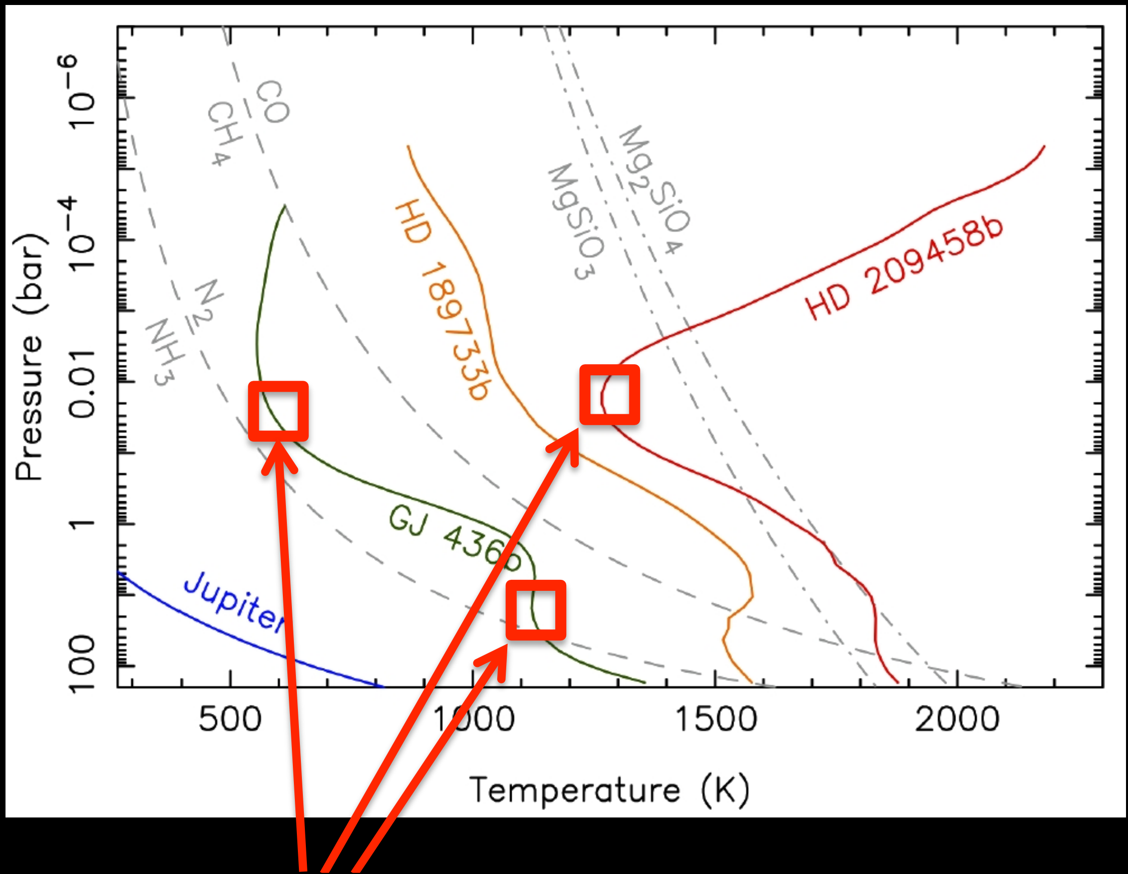
SIMPLE: λ = 0.84 – 2.5 µm
R = 100,000
METIS: λ = 3 – 14 µm
R = 100,000



Snellen et al. (2011)

Synergies with ELTs





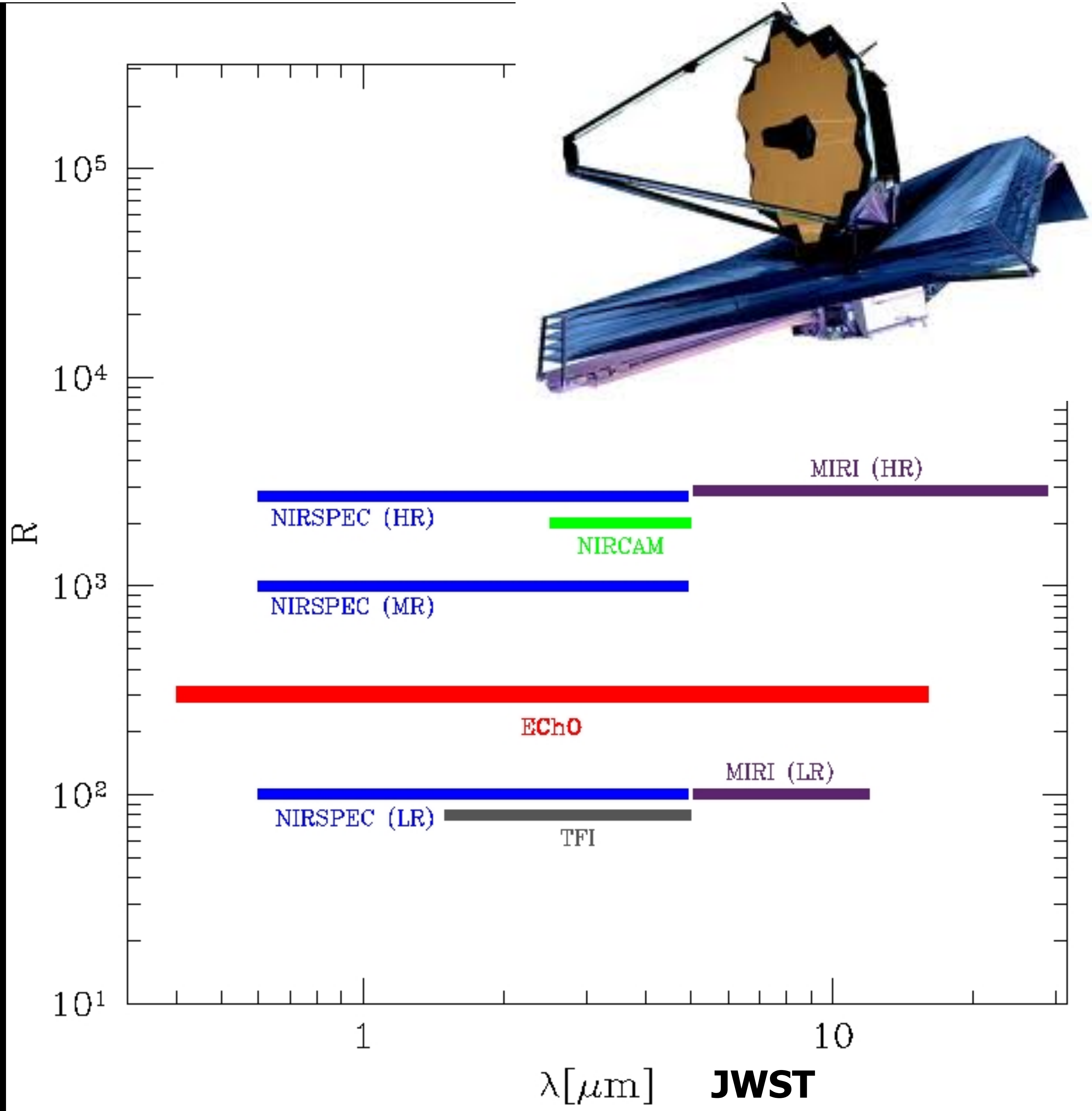
Zoomed in detailed observations

- EChO will provide T-P profiles of wide variety of planets.

- EChO will allow for clear detection and location of thermal inversion layers.

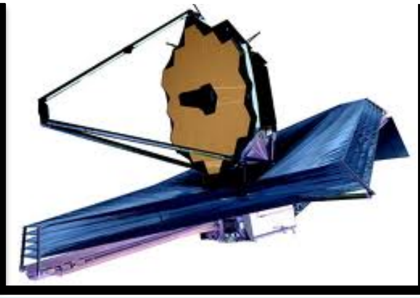
-EChO will not be able to tell chemical composition of inversion layers.

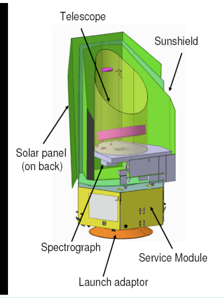
-E-ELT will be able to zoom into specific areas of atmospheres, and answer composition questions in detail.



R
10^5
10^4
10^3
10^2
10^1
1
10
λ[μm]
MIRI (HR)
NIRSPEC (HR)
NIRCAM
NIRSPEC (MR)
EChO
MIRI (LR)
NIRSPEC (LR)
TFI

JWST

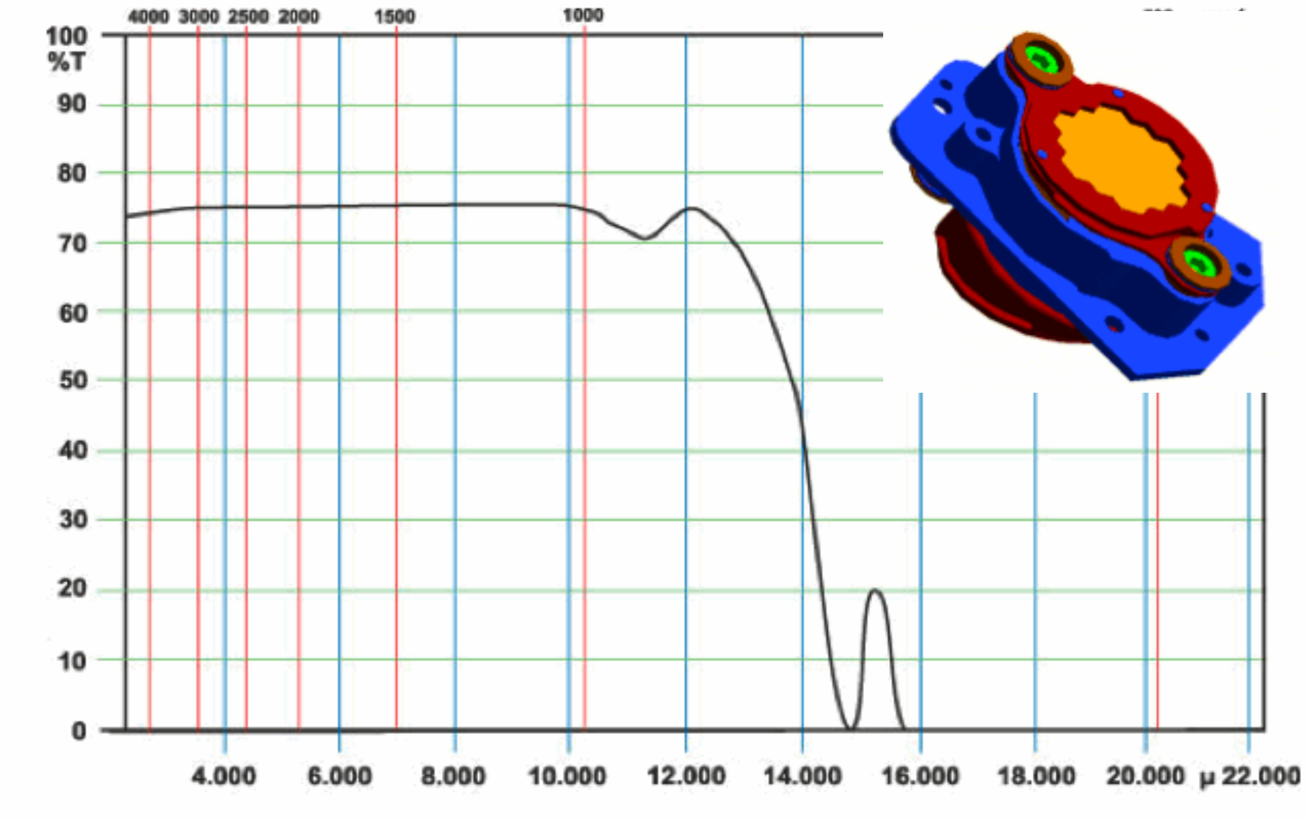


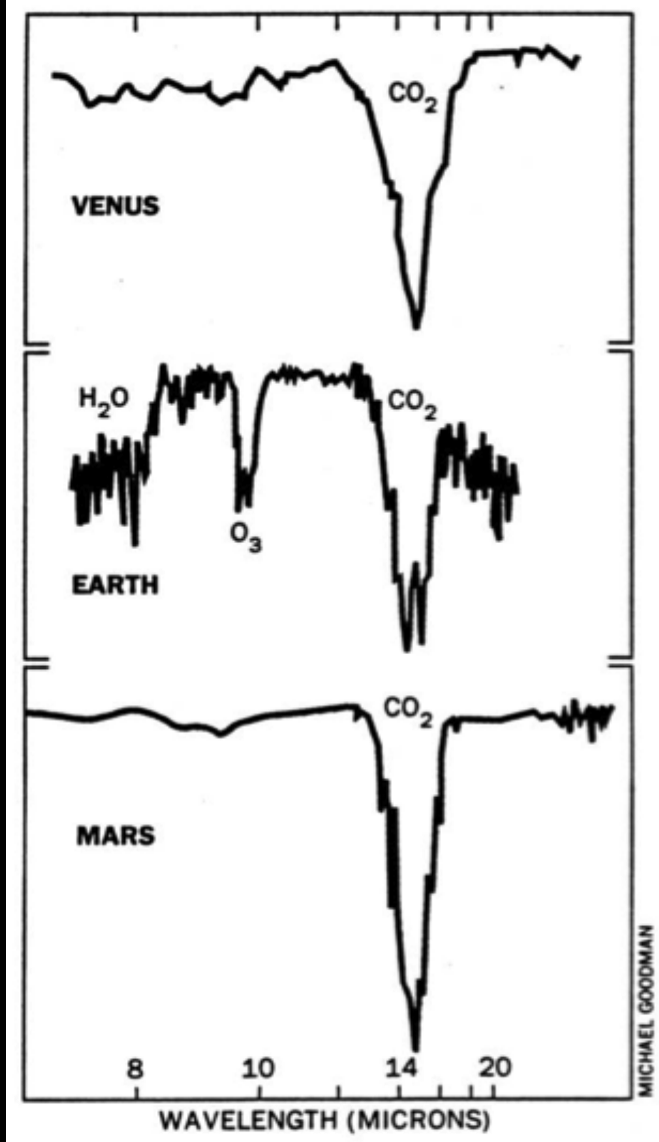


JWST : Observatory Few objects	ECHO : Dedicated mission. A survey of exoplanets (diversity).
Need to combine 4 observations NIRSPEC + MIRI to cover 1-16 µm. CO2 band at 15 µm in a dichroic. Saturation limit with some instruments	Simultaneously 0.4-16 µm Key to correct stellar activity and understand meteorology.
Instruments optimized for background limited observations. -Lots of moving parts + segmented mirror --> Systematic errors will most likely be harder to control (especially below 5 µm)	Instrument optimized for photon noise limited observations. -No moving parts (except tit-tilt) -Monolithic miror -→ By design, minimisation of systematic errors.
Bigger mirror, higher resolution, higher S/N over short wavelength range.	Long term stability limited by photon noise.

Habitable super Earth, CO2 with MIRI LRS

- CO2 band at 15 µm observed with R~10
- LRS ZnS prism cuts at 14 µm – so observations with MRS at lower S/N, & 2x visits
- H2O,CH4, NH3, O3 bands are visible





Menu : M dwarf in 2020

- Super Earth orbiting M dwarf are abundants

- Several dedicated projects:
- MEARTH : 2000 late M dwarfs Ro < 0.33Ro, in progress
- APACHE : extension of MEARTH, starting
- CARMENES : RV in IR, late M dwarfs, start in 2014
- 2MASS+WISE+GAIA : hunting for close and late M dwarfs

- SPIROU : CFHT 2014, monitoring 800 M dwarfs -> 80 planets M<20 ME
- For Early M : HAT, HARPS, ESPRESSO

- PLATO : 20 % of sky, VIS, submitted to ESA, 2018 (early M)
- ELEKTRA : all sky, IR, submitted to NASA, 2016 (all M with K<10)
- TESS : all sky, I band, submitted to NASA, 2016 (earlier than M2)

Conclusions

ECHO : ESA M class mission (2020)

Dedicated 1.4m satellite, 0.4-16 microns (R=300-50)

Study of a large portfolio of exoplanets (hot, warm, habitable)

atmospheres, abundance, dynamics, …

ECHO is a very useful friend for the giants !

some targets at higher resolution S/N at selected wavelength (JWST)

Very high resolution of transiting planets (ELTs)

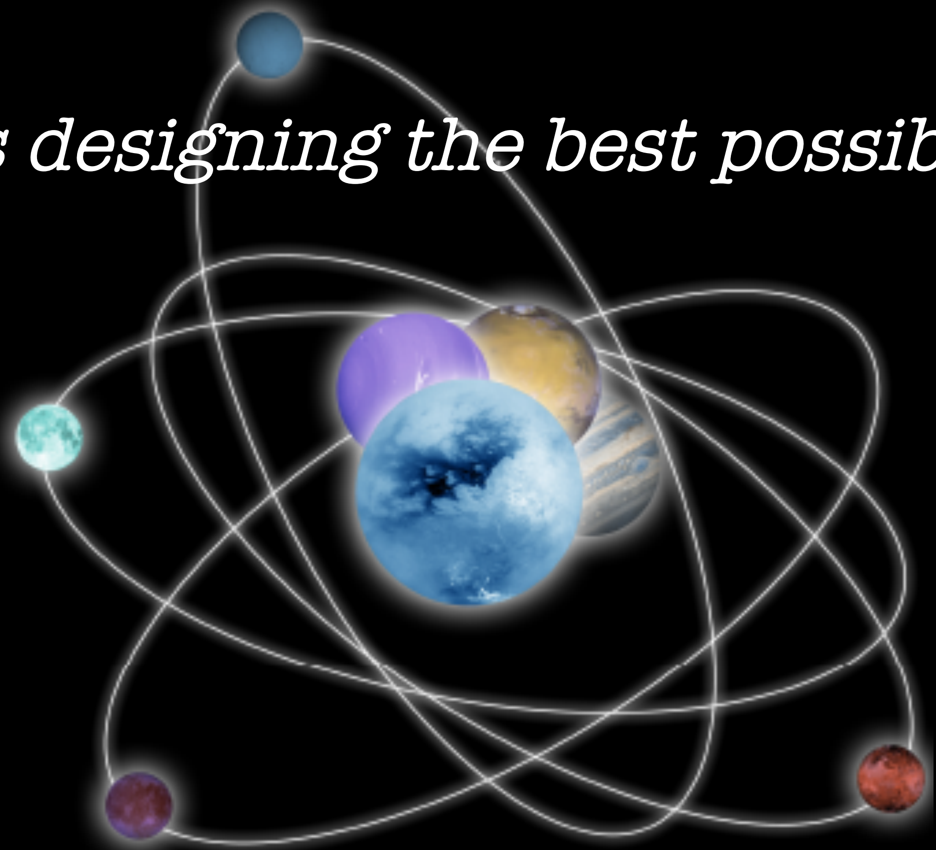
ECHO is a (M class) giant :

ECHO needs to be fed with super Earth around M4+ dwarfs

All giants wants to be fed with habitable super Earth
orbiting M dwarfs, late ones.

Join the EChO team!

Help us designing the best possible mission



http://echo-spacemission.eu/