Searching for oxygen in the atmospheres of exo-Earths from the ground

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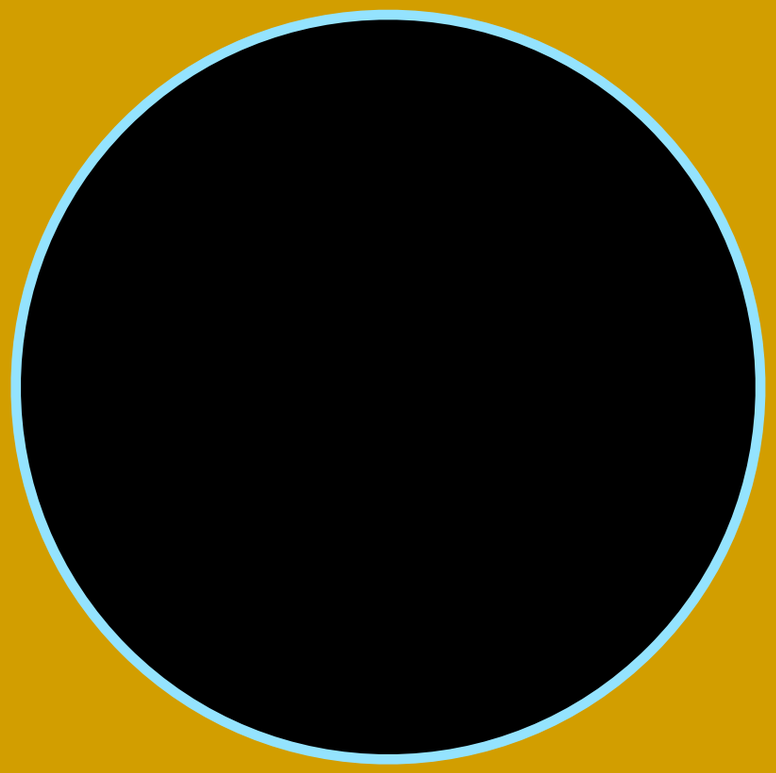
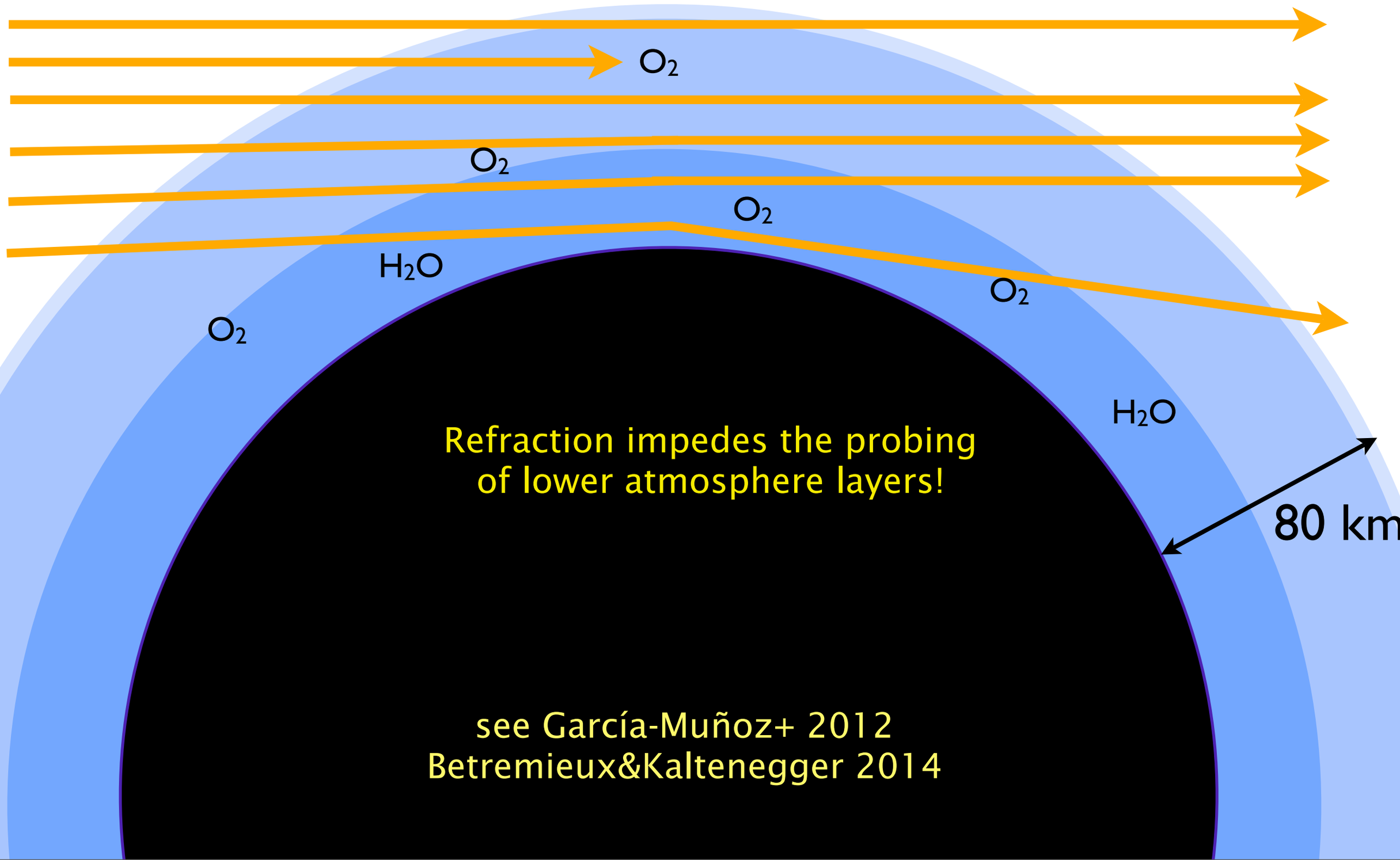
Image credit: ESA

Transmission spectroscopy (transiting planet; hi-res R~100,000)



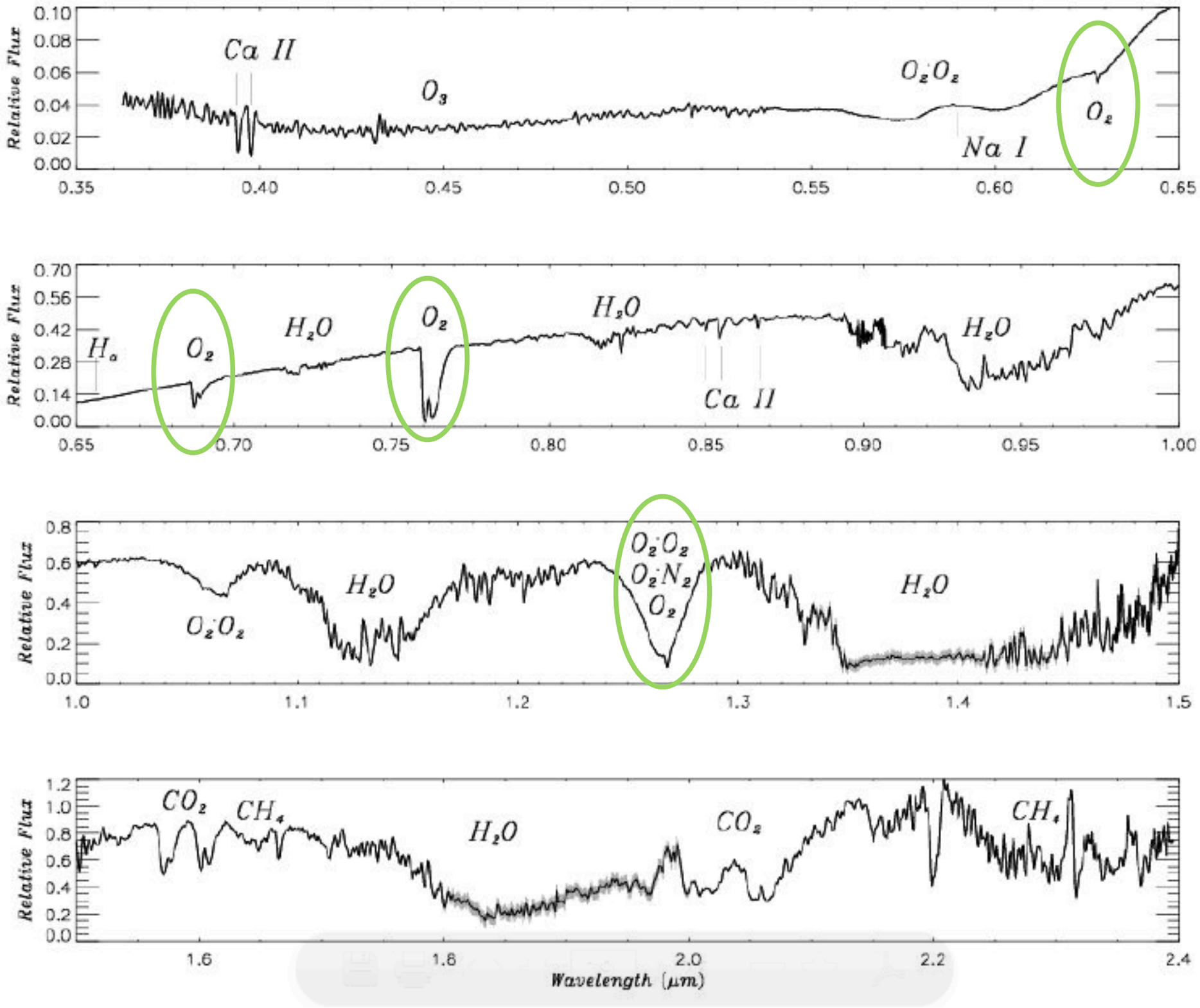
Atmosphere ring ~1/32 planet disk .
~1/520,000 of solar disk

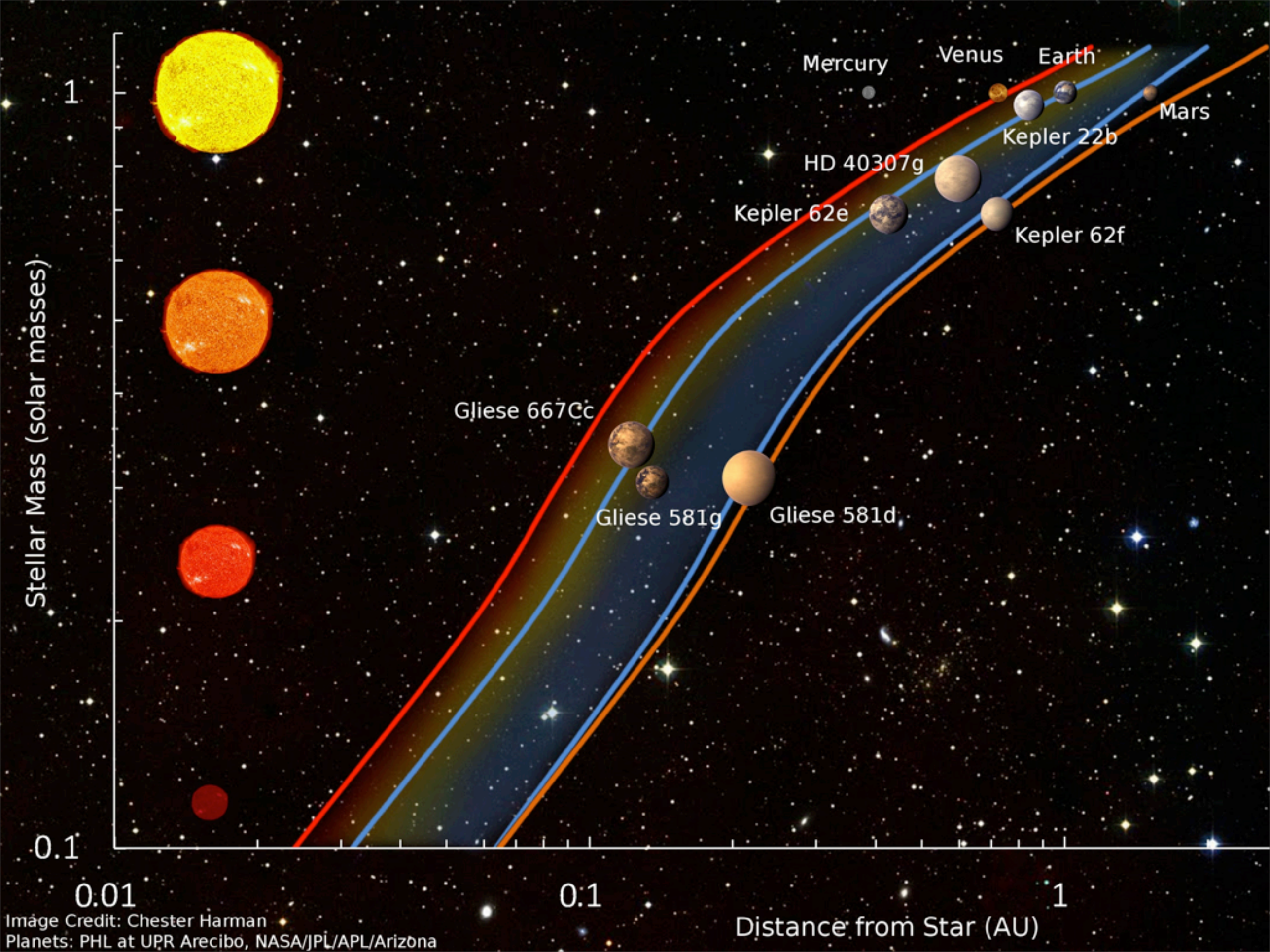
Starlight passing through different atmosphere layers ...



Transmission spectrum of the Earth's atmosphere

credit: Pallé+ 2009, Nature, 459, 814




Mercury
Venus
Earth
Mars
Kepler 22b
HD 40307g
Kepler 62e
Kepler 62f
Gliese 667Cc
Gliese 581g
Gliese 581d
1
0.1
0.01
0.1
1
Stellar Mass (solar masses)
Distance from Star (AU)
Image Credit: Chester Harman
Planets: PHL at UPR Arecibo, NASA/JPL/APL/Arizona

Why investigating exo-Earths around M-dwarfs?

- short period planets are in the habitable zone

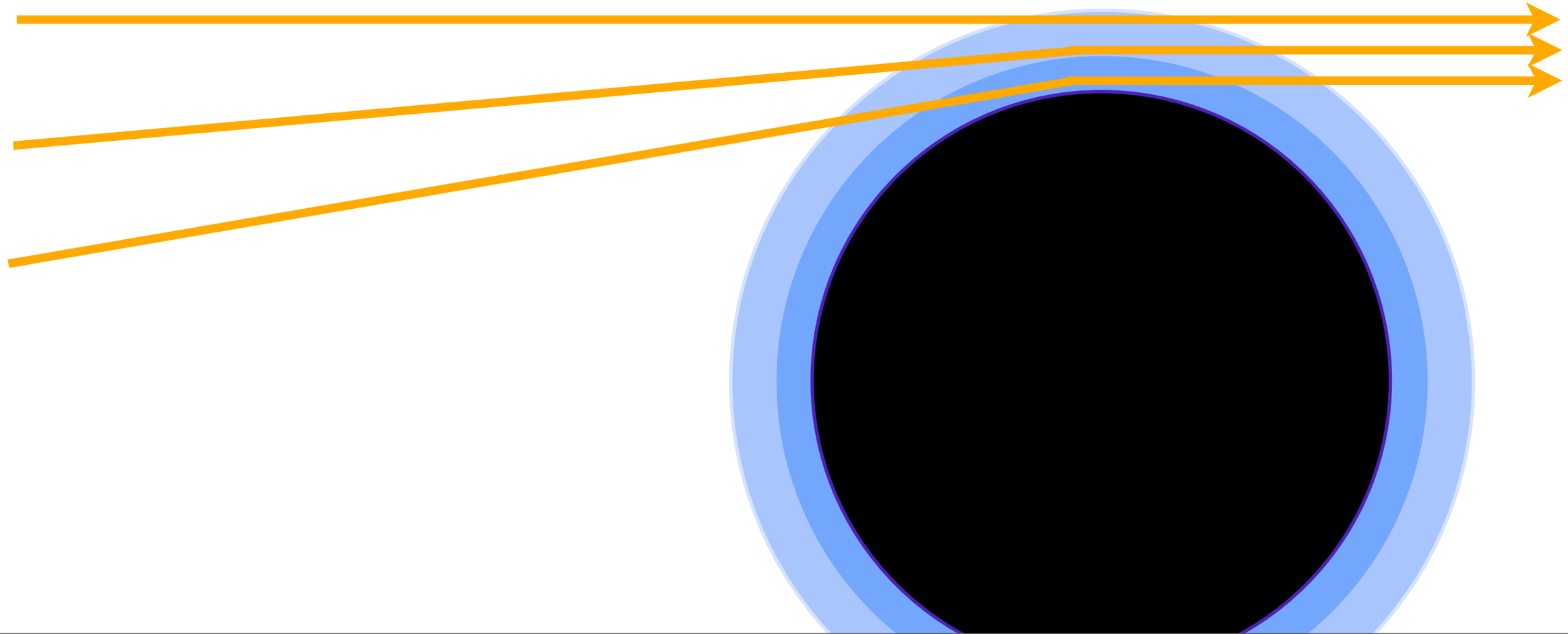
- can observe a large number of transits in a relatively short time

- area ratio between M-dwarfs and planet atmosphere ring more favourable (~10,000 to 100,000)

- hardly no light losses due to refraction
  - can probe lower atmosphere parts

Hardly no light losses due to refraction in transmission spectra of habitable planets around M-dwarfs.

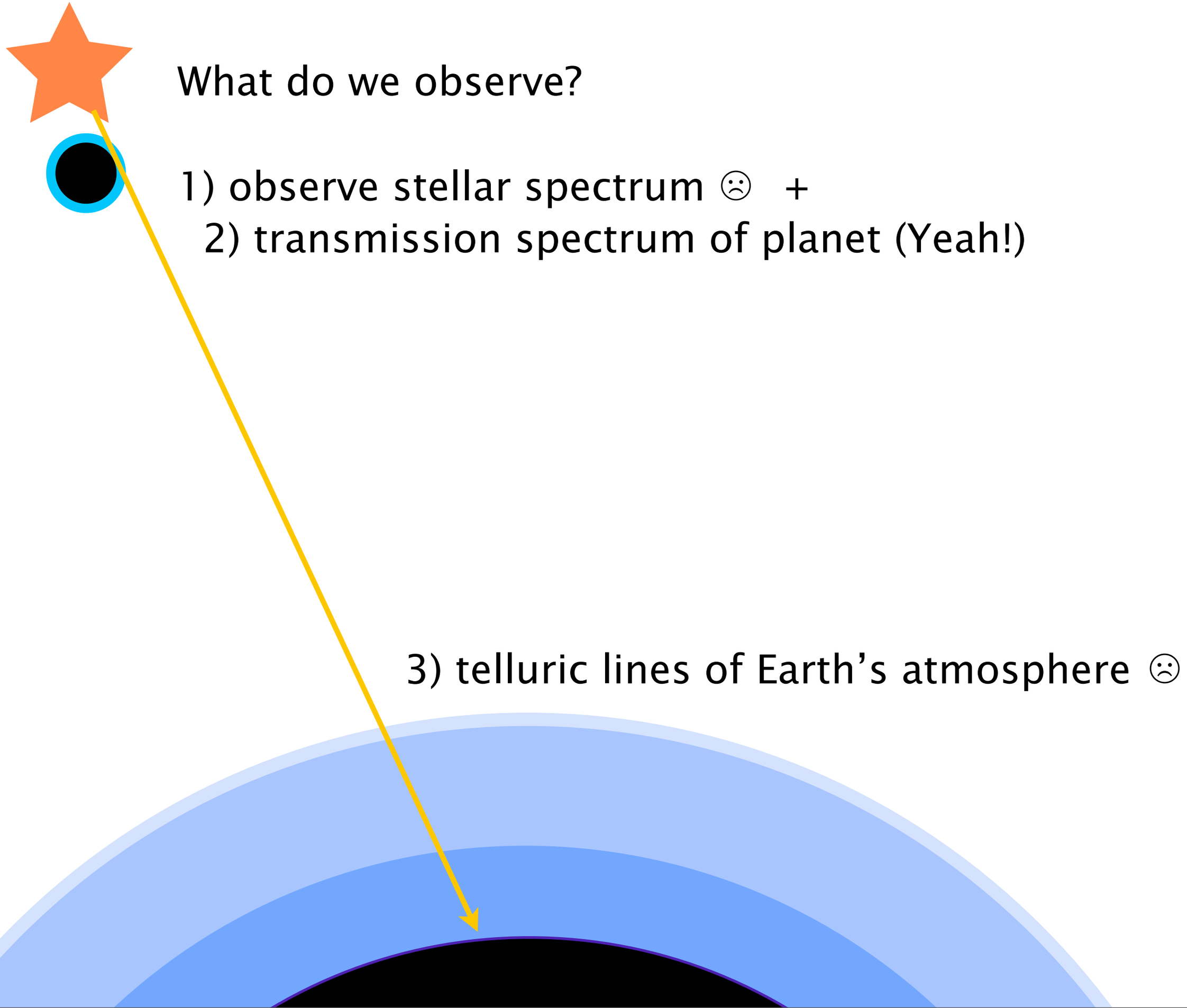
Star is close to planet and appears about 10x larger in the sky then the Sun seen from Earth.



What do we observe?

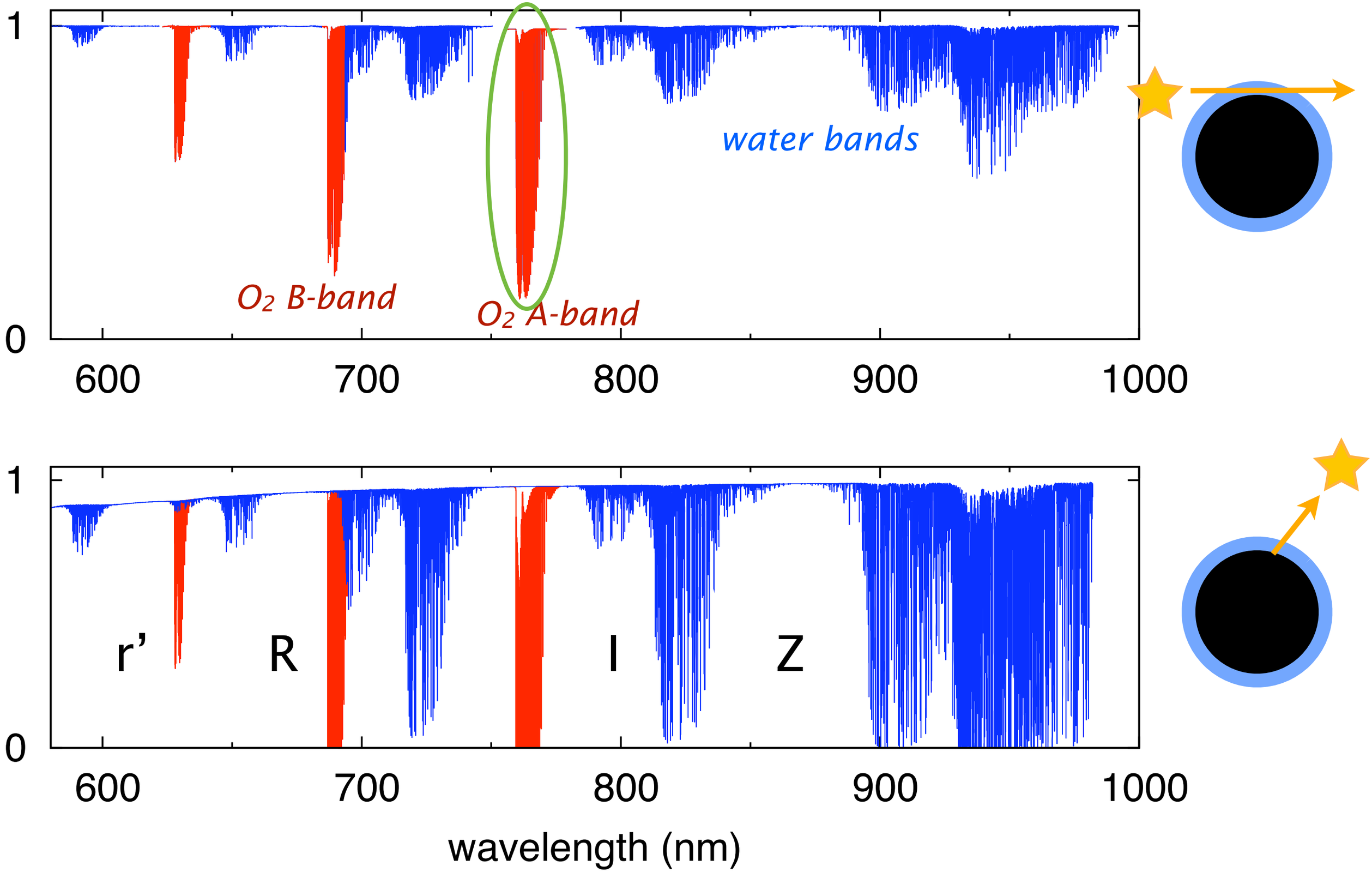
1) observe stellar spectrum ☹ +
2) transmission spectrum of planet (Yeah!)

3) telluric lines of Earth's atmosphere ☹

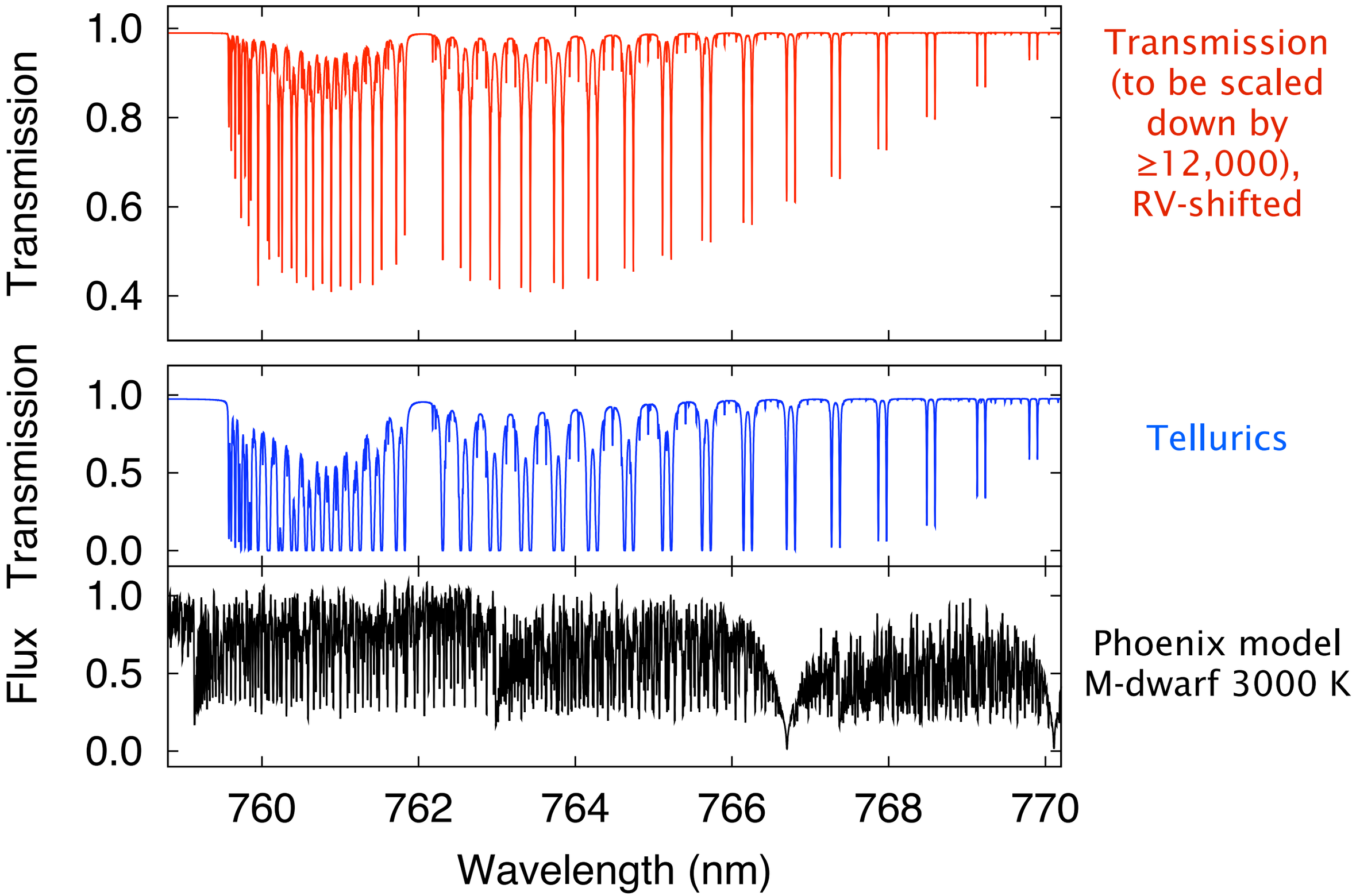


Transmission spectrum vs. telluric spectrum

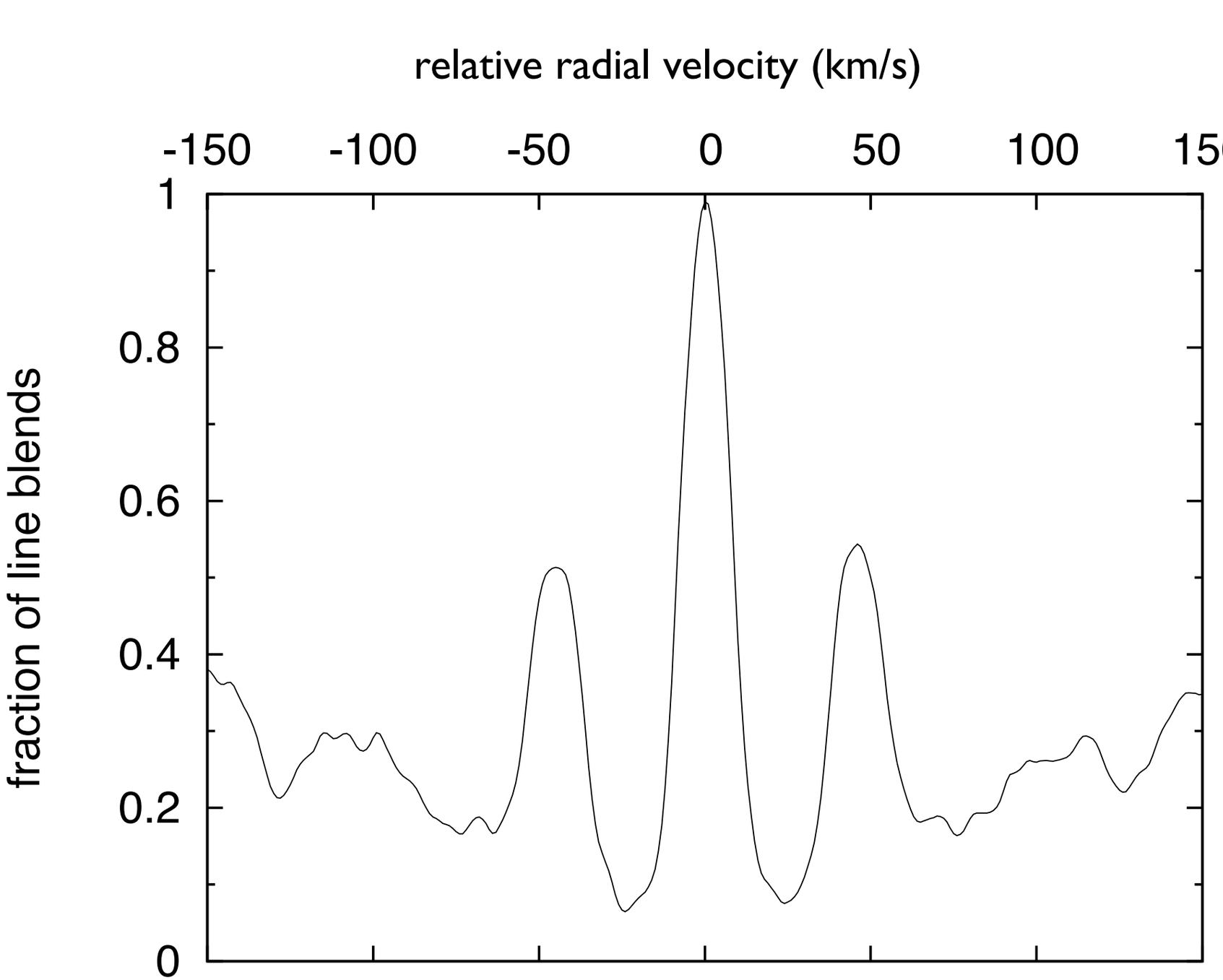
(calculated with LBLRTM + HITRAN)

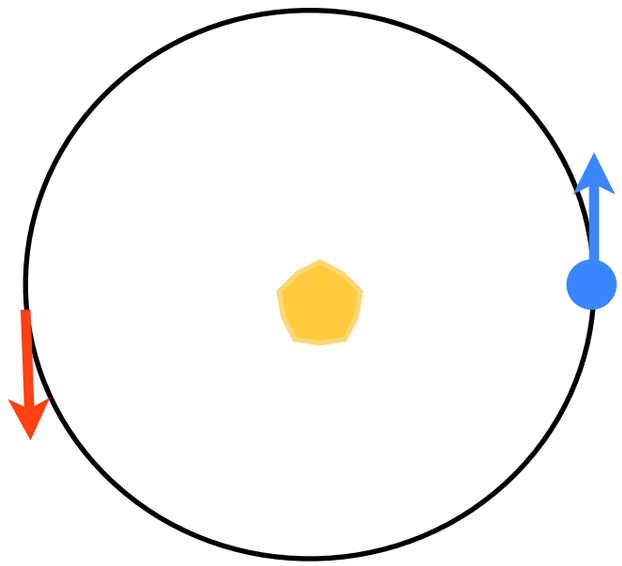


The O_2 A-band ...


Transmission
1.0
0.8
0.6
0.4
Transmission (to be scaled down by ≥12,000), RV-shifted
Transmission
1.0
0.5
0.0
Tellurics
Flux
1.0
0.5
0.0
Phoenix model M-dwarf 3000 K
760
762
764
766
768
770
Wavelength (nm)

Optimize the observations ...





barycentric velocity
of Earth (up to 30 km/s)

Number of transits needed to attain a 3σ detection with 39m E-ELT/UVES ...

	area ratio	M_I	P (days)	transit duration (h)	number transits	hours
M1V	125 000	7.7	43	4.0	28	~110
M2V	100 000	8.3	33	3.4	29	~100
M3V	80 000	8.8	27	3.0	29	~90
M4V	35 000	10.0	16	2.1	21	~45
M5V	21 000	11.2	10	1.5	31	~47
M6V	12 000	12.4	6	1.1	45	~50

... at a distance of 5 pc, including 20% red-noise.

Number of transits needed to attain a 3σ detection with 39m E-ELT/G-CLEF ...

	area ratio	M_I	P (days)	transit duration (h)	number transits	hours
M1V	125 000	7.7	43	4.0	17	~70
M2V	100 000	8.3	33	3.4	19	~65
M3V	80 000	8.8	27	3.0	19	~55
M4V	35 000	10.0	16	2.1	14	~30
M5V	21 000	11.2	10	1.5	21	~32
M6V	12 000	12.4	6	1.1	31	~34

... at a distance of 5 pc, including 20% red-noise.

Conclusions

- detection of O2 via high-resolution spectroscopy from the ground is a very challenging task

- most suitable for M4V at < 8 pc (26 ly). Need 30 hours+

- need to optimize spectrographs (e.g. preslit optics, throughput, detectors)

- other observing techniques more efficient?
  ... work in progress!

(check out literature: ***Rodler + López-Morales 2014, ApJ****;*
Snellen+ 2013, ApJ; Kaltenegger + Traub 2009, ApJ

How many M-dwarf neighbors do we know?