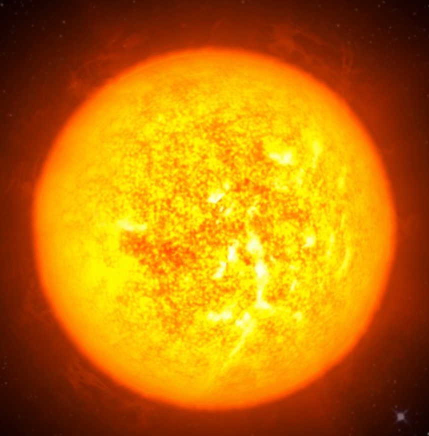
Characterization of exoplanetary atmospheres

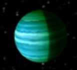
Exoplanet transit spectroscopy

Erik Aronson

Contrast – Reflected light

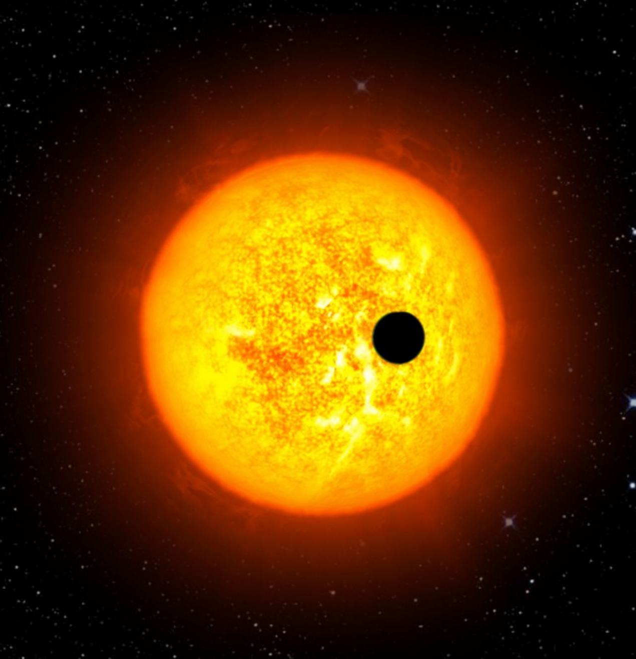


HD189733b
Semi-major axis: 0.03 au
Planet radius: 1.14 $R_{Jupiter}$
Contrast, $I_P/I_S = 1 \cdot 10^{-4}$



GJ1214b
Semi-major axis: 0.014 au
Planet radius: 2.7 R_{Earth}
Contrast, $I_P/I_S = 1 \cdot 10^{-5}$

Contrast – Transits



HD189733b

Stellar radius: 0.76 R_{Sun}

Planet radius: 1.14 $R_{Jupiter}$

Contrast, $I_P/I_S = 1 \cdot 10^{-3}$

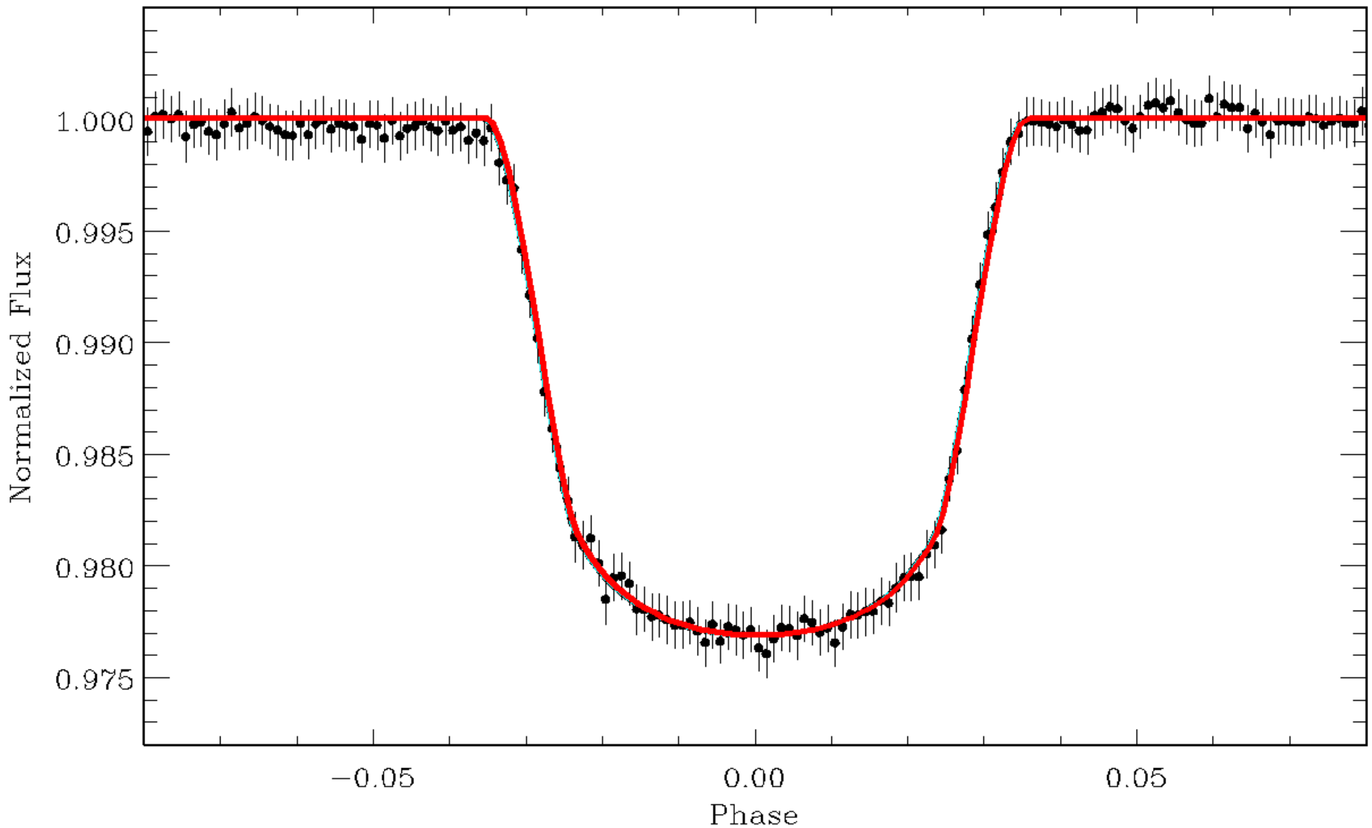
GJ1214b

Stellar radius: 0.21 R_{Sun}

Planet radius: 2.7 R_{Earth}

Contrast, $I_P/I_S = 5 \cdot 10^{-4}$

Exoplanet transits as detection method



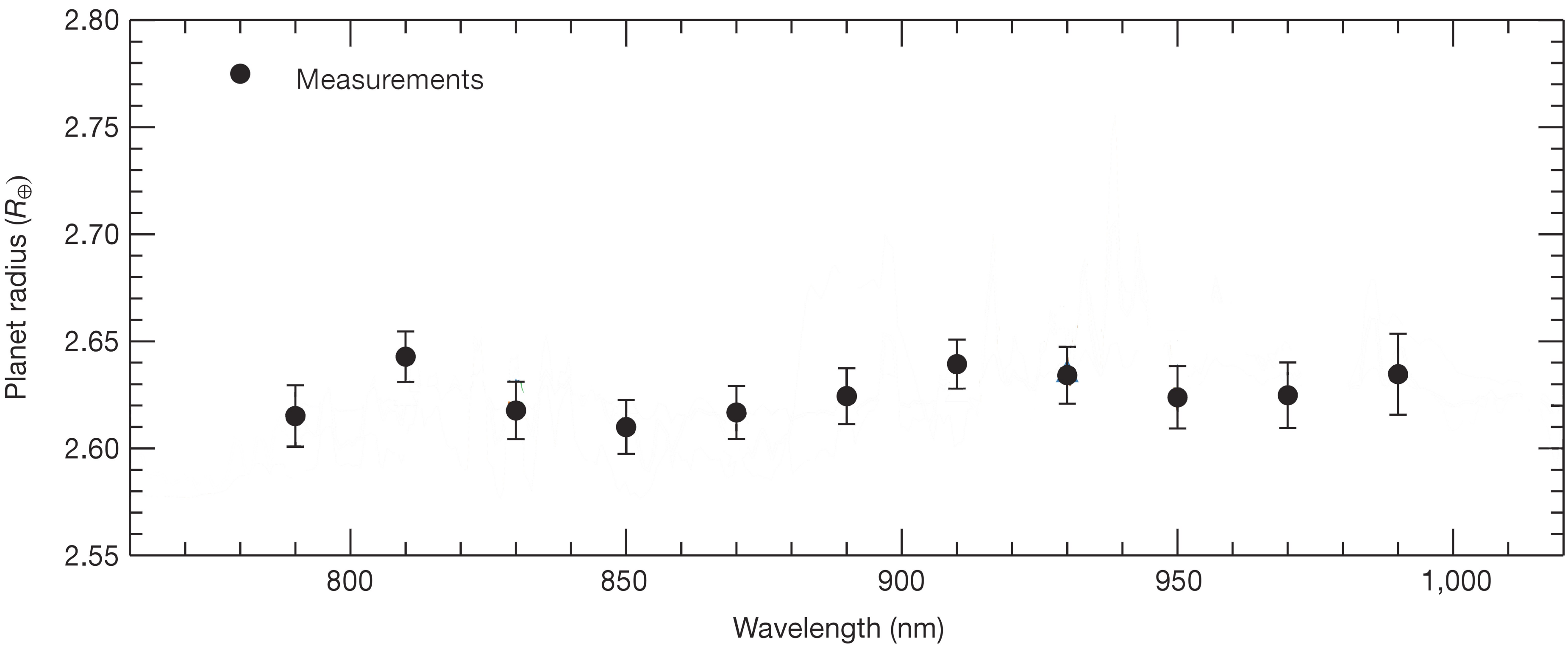
Space based missions
- Kepler
- CoRoT

Ground based
- WASP
- HAT
- XO
(and many more)

Future missions
- Plato 2.0
- TESS

Characterization of exoatmospheres

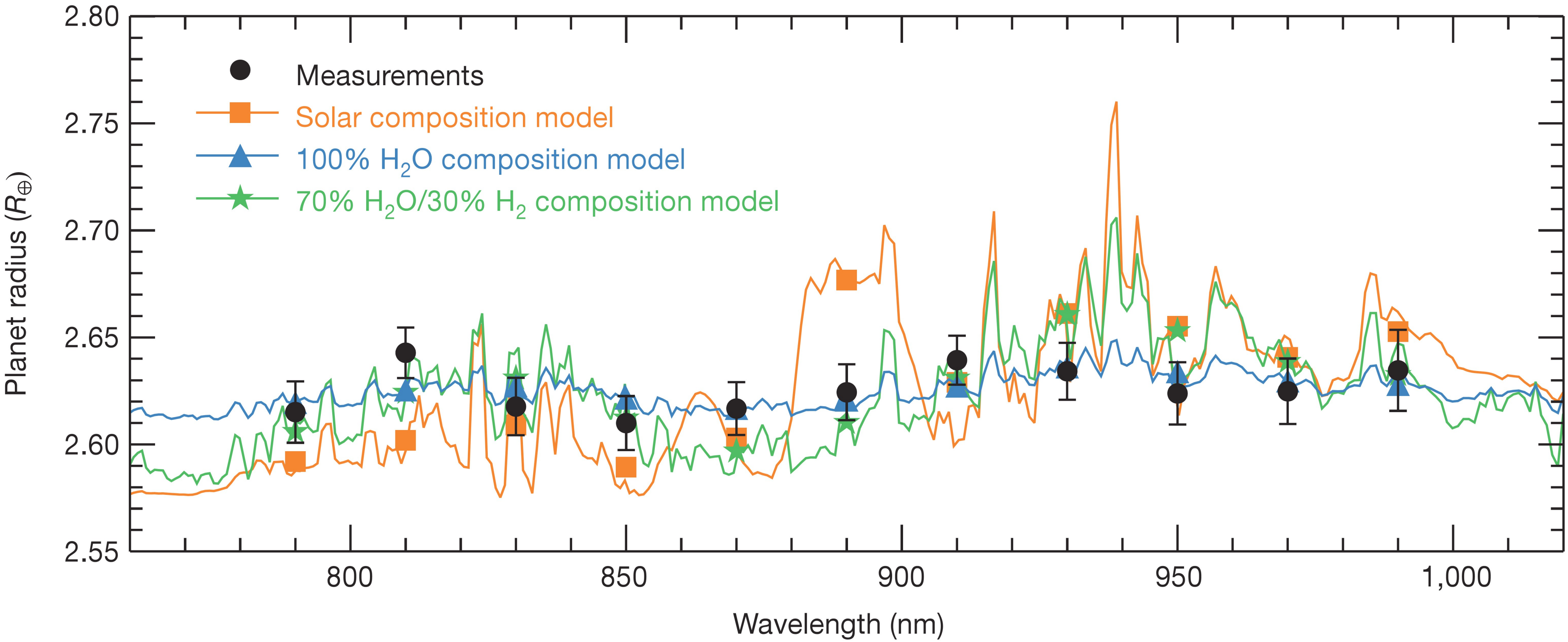
GJ1214b



Bean et al. (2010)

Characterization of exoatmospheres

GJ1214b



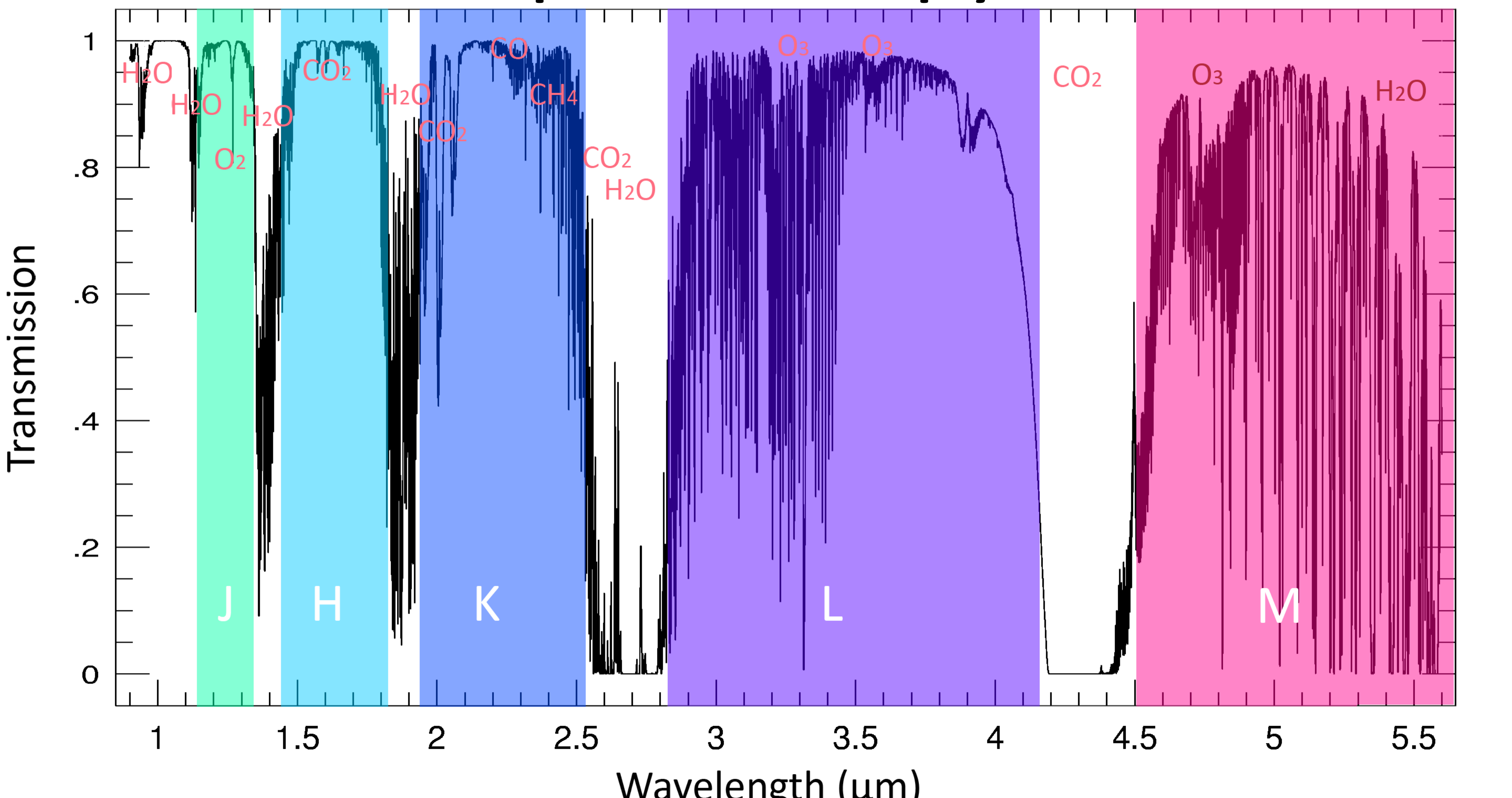
Bean et al. (2010)

Solution; High resolution NIR spectroscopy

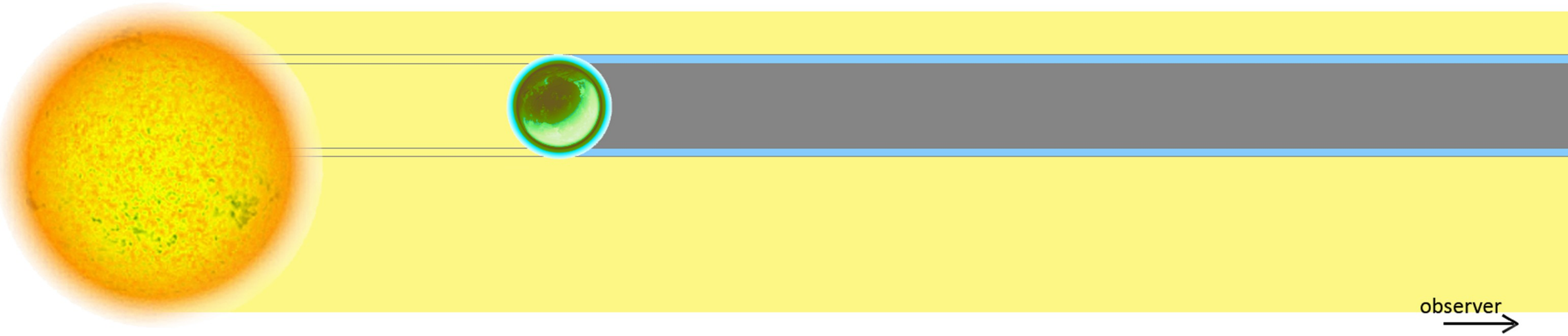
-Why near infra-red?

-Why high resolution ($\lambda/\Delta\lambda > 50{,}000$)

Solution; High resolution NIR spectroscopy



Method

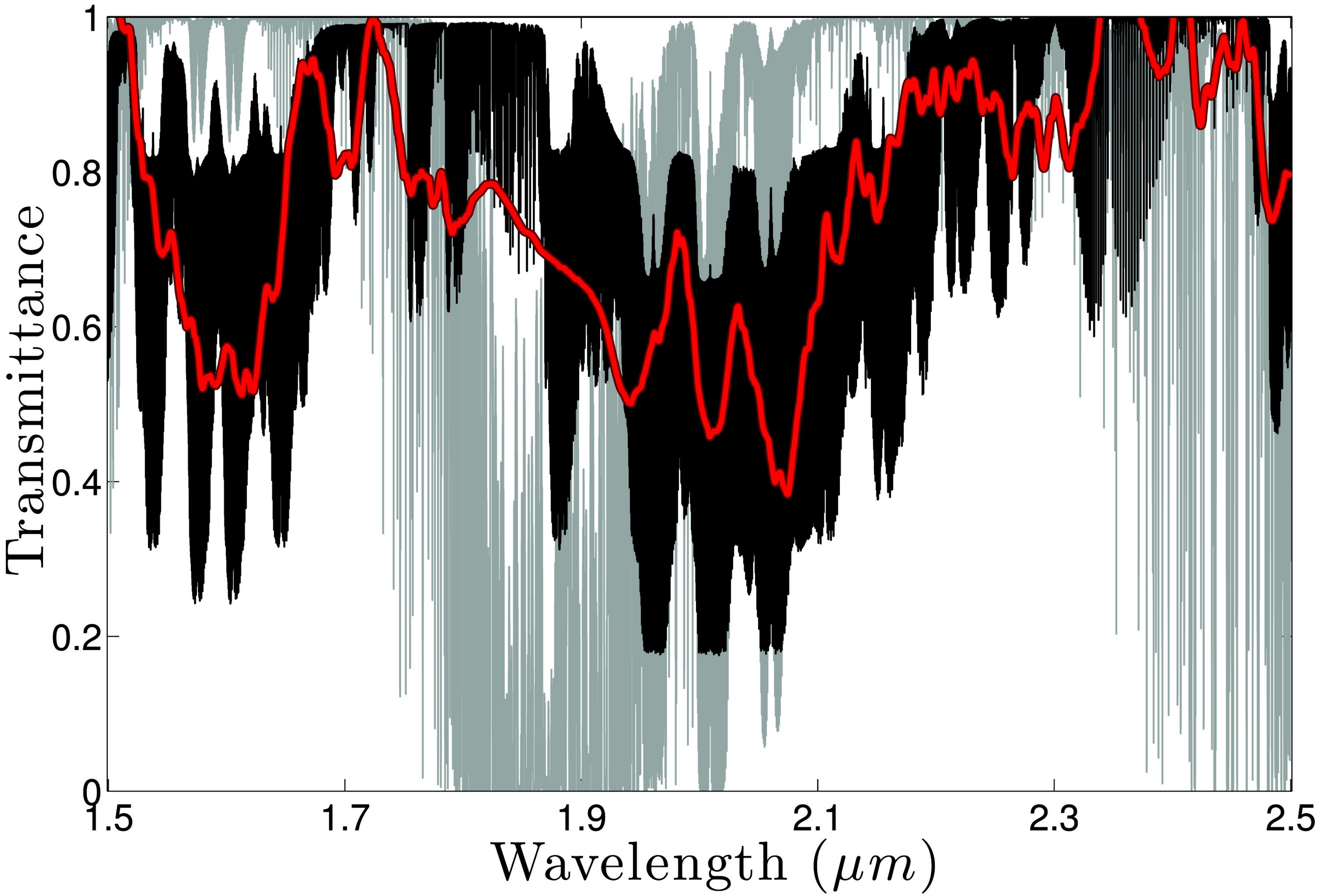


$$S(\lambda,\phi) = \left[F(\lambda) - \delta^{p+a} \cdot I_{\mu}^{p+a}(\lambda,\phi) + \delta^{a} \cdot I_{\mu}^{a}(\lambda,\phi) \cdot P(\lambda)\right]_{\chi_\phi} \cdot T(\lambda,\phi)$$

$$\Omega \equiv \sum_{\phi\lambda} \left[\left(P(\lambda) \cdot T_{\chi_\phi}(\phi,\lambda) \otimes \Gamma_{in} \right) - \frac{S_{\chi_\phi} - \left(F(\lambda) - \delta^{p+a} \cdot I^{\mu}(\phi,\lambda) \right) \otimes \Gamma_{in} \cdot T_{\chi_\phi}(\phi,\lambda) \otimes \Gamma_{in}}{\delta^{a} \cdot I^{\mu}(\phi,\lambda) \otimes \Gamma_{in}} \right]^2 +$$

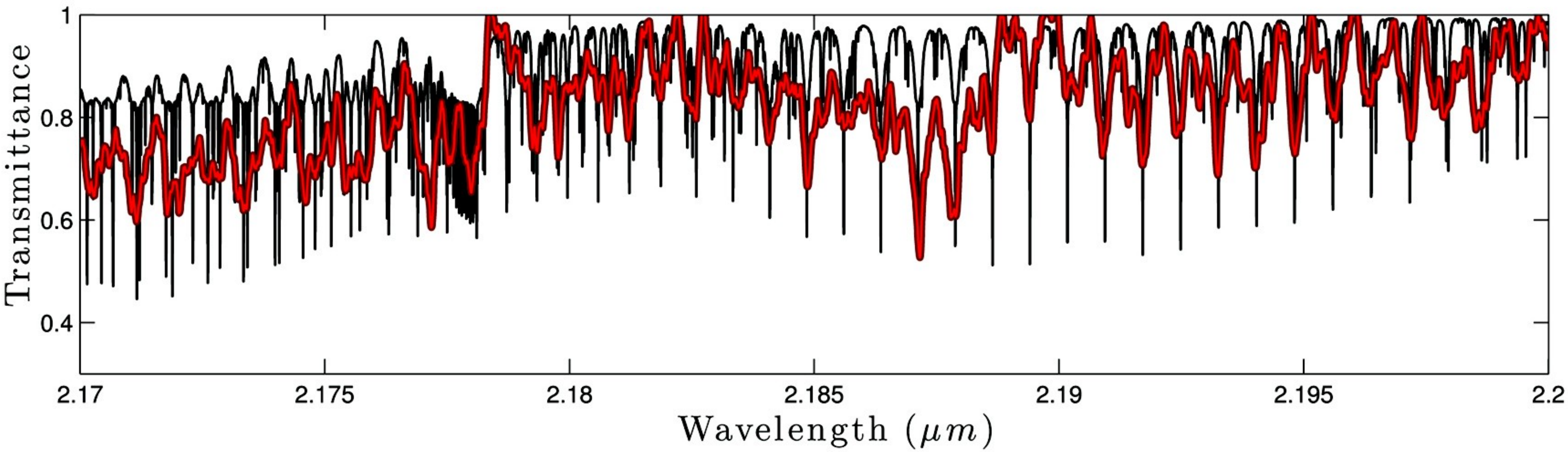
$$\Lambda \cdot \sum_{\lambda} \left(\frac{dP(\lambda)}{d\lambda} \right)^2 = min$$

Test of method



Test of method

Hot Jupiter, 15 transits

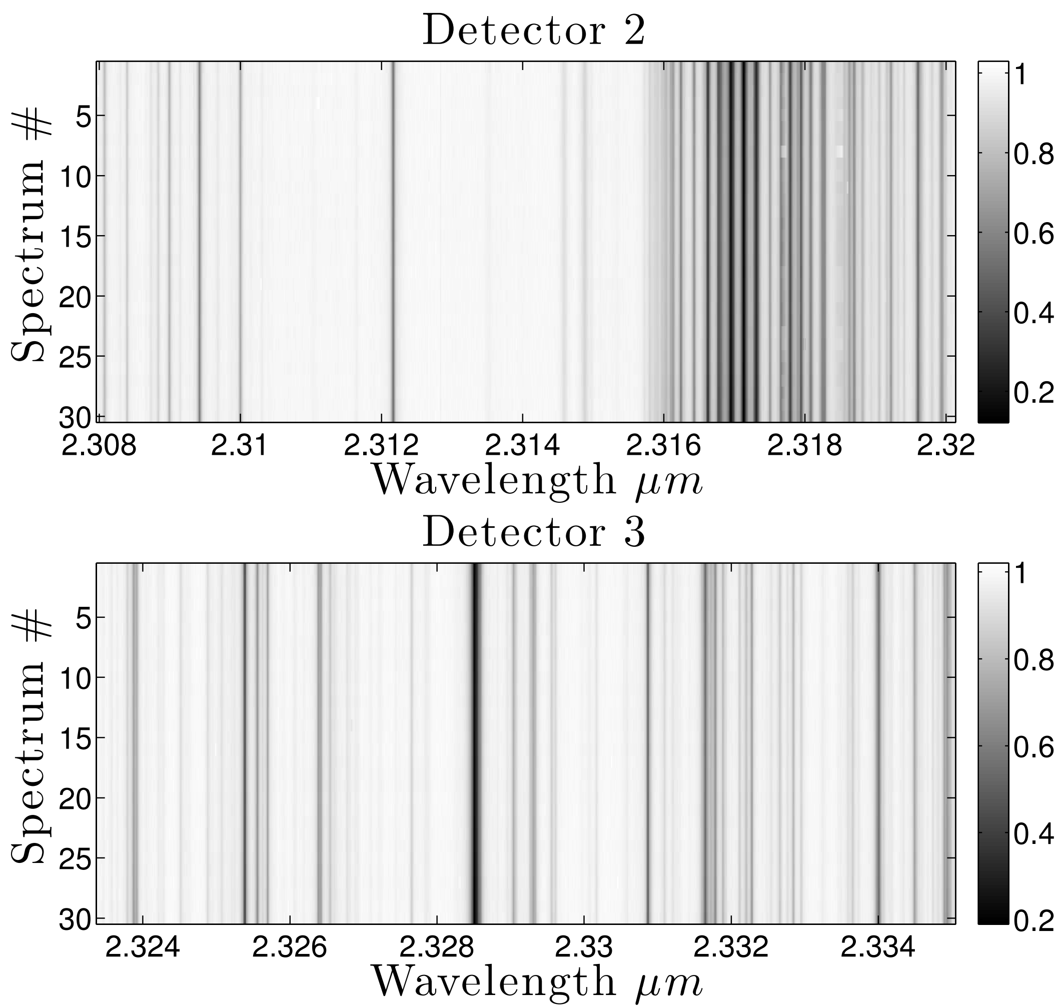


Instrumental requirements

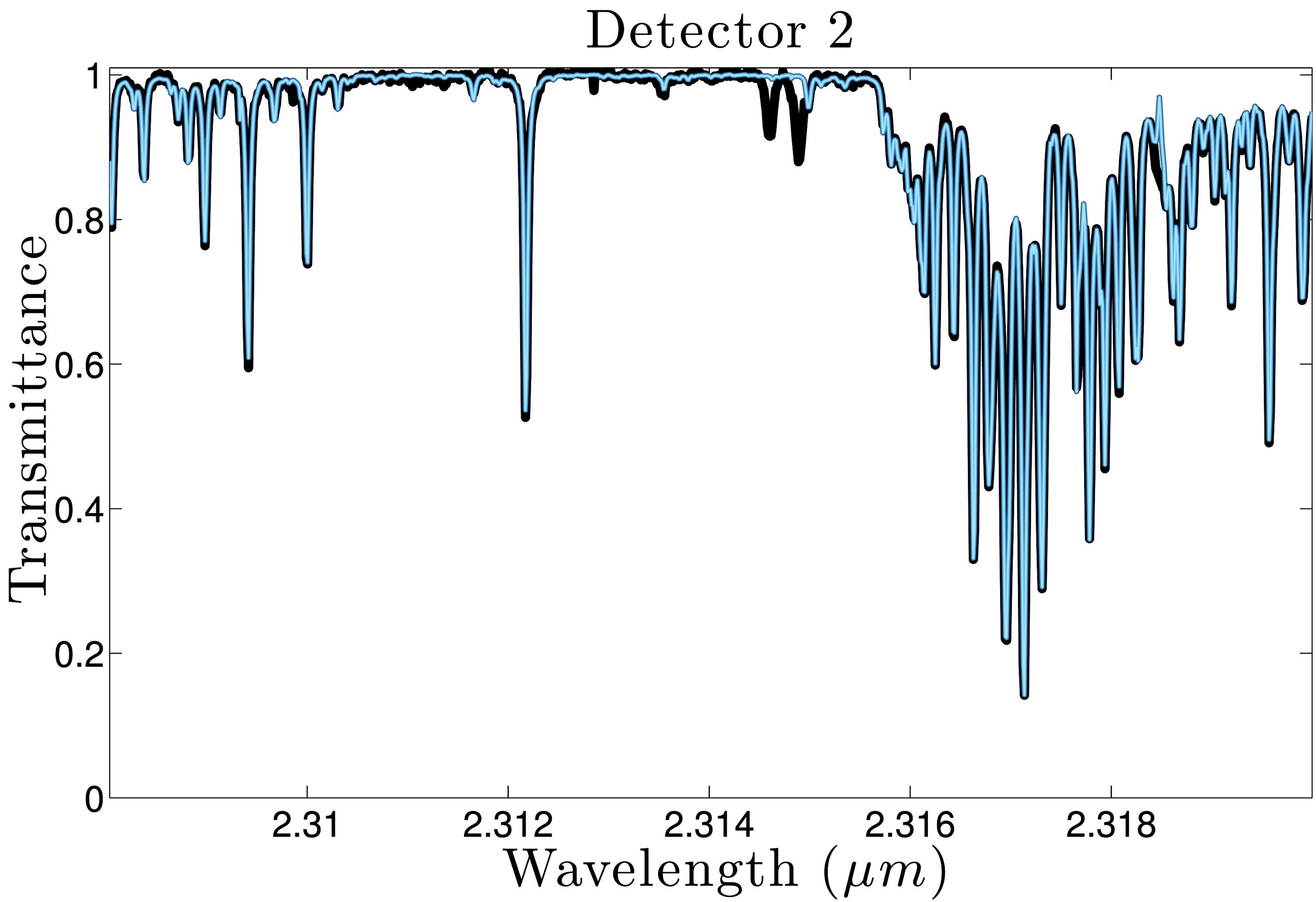
1. High resolution resolution
2. Wavelength region
3. Simultaneous spectral coverage
4. Photon collecting area

HD 209458b

Transit of hot Jupiter HD209458b
VLT, CRIRES
51 spectra (30 during transit)
Snellen et al. (2009)

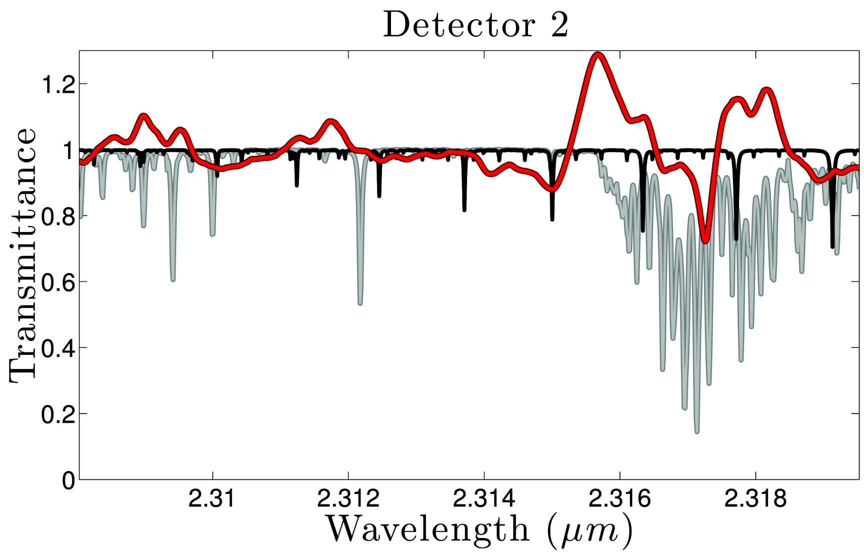


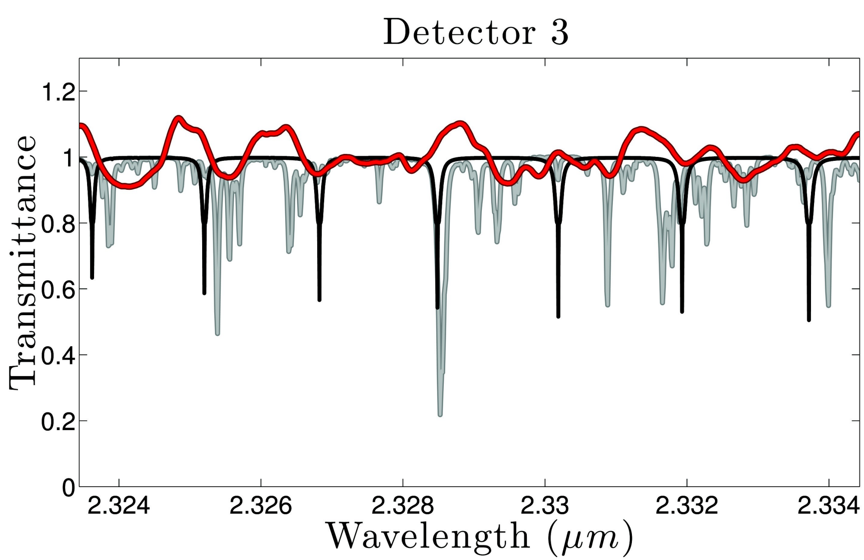
HD 209458b

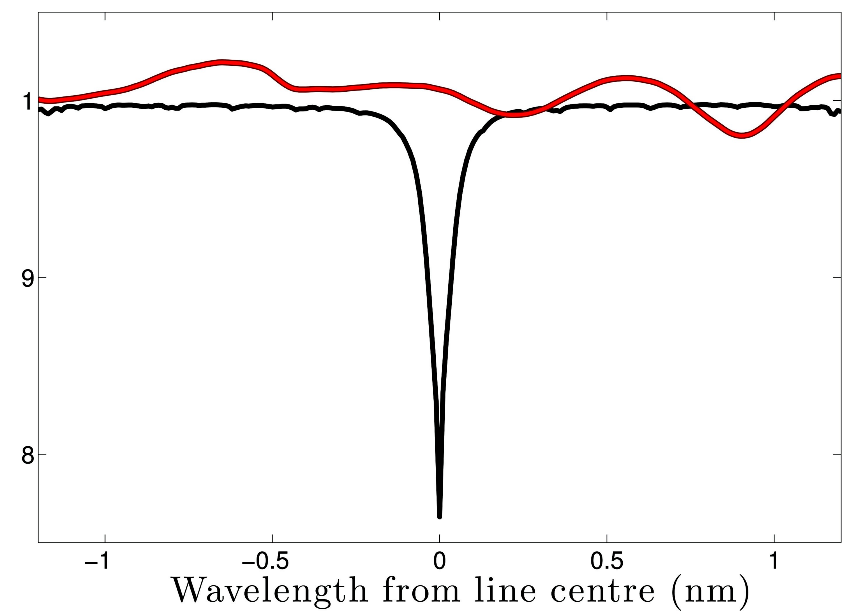


Detector 2
Transmittance
1
0.8
0.6
0.4
0.2
0
2.31
2.312
2.314
2.316
2.318
Wavelength (μm)

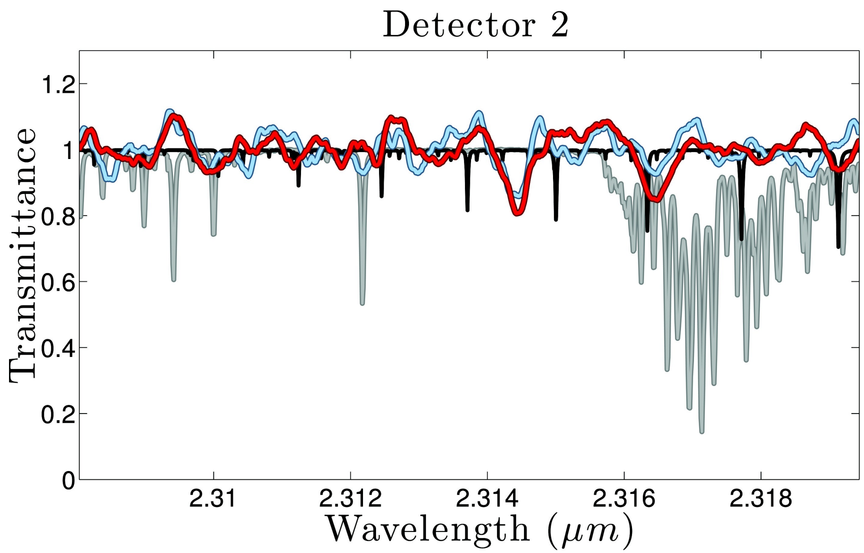
Results, HD 209458b

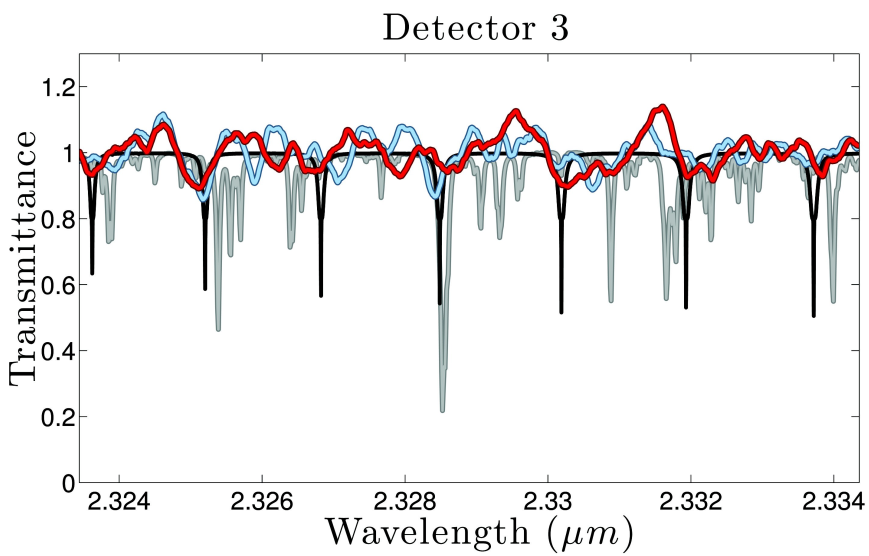






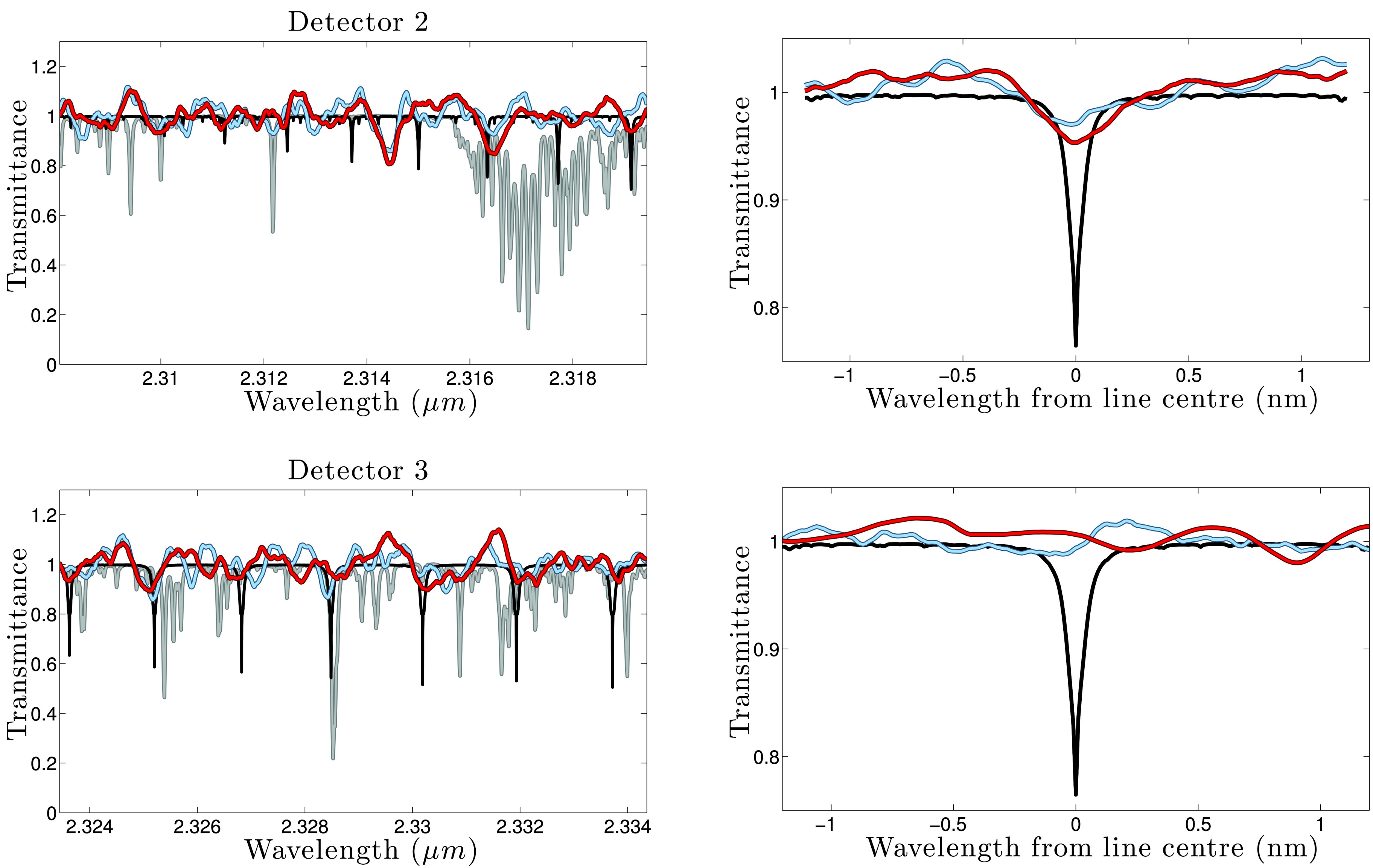
Simulations, HD 209458b





Blue, 4 transits
Red, 10 transits

Simulations, HD 209458b



Conclusion

- Method promising for large wavelength regions once suitable instruments are ready
- Short regions require many transits, other methods can be more successful