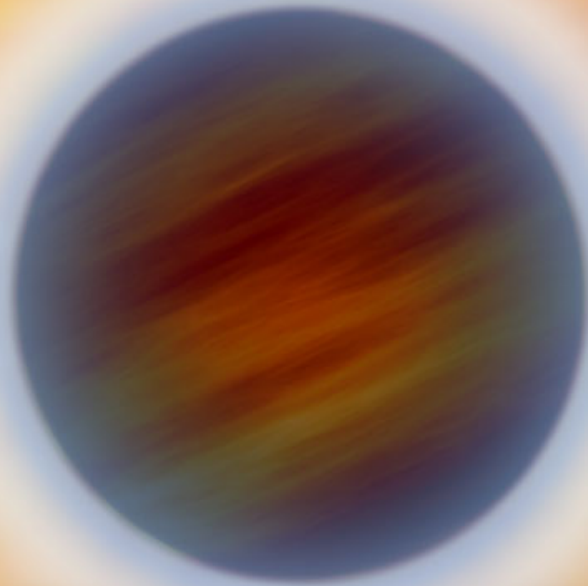
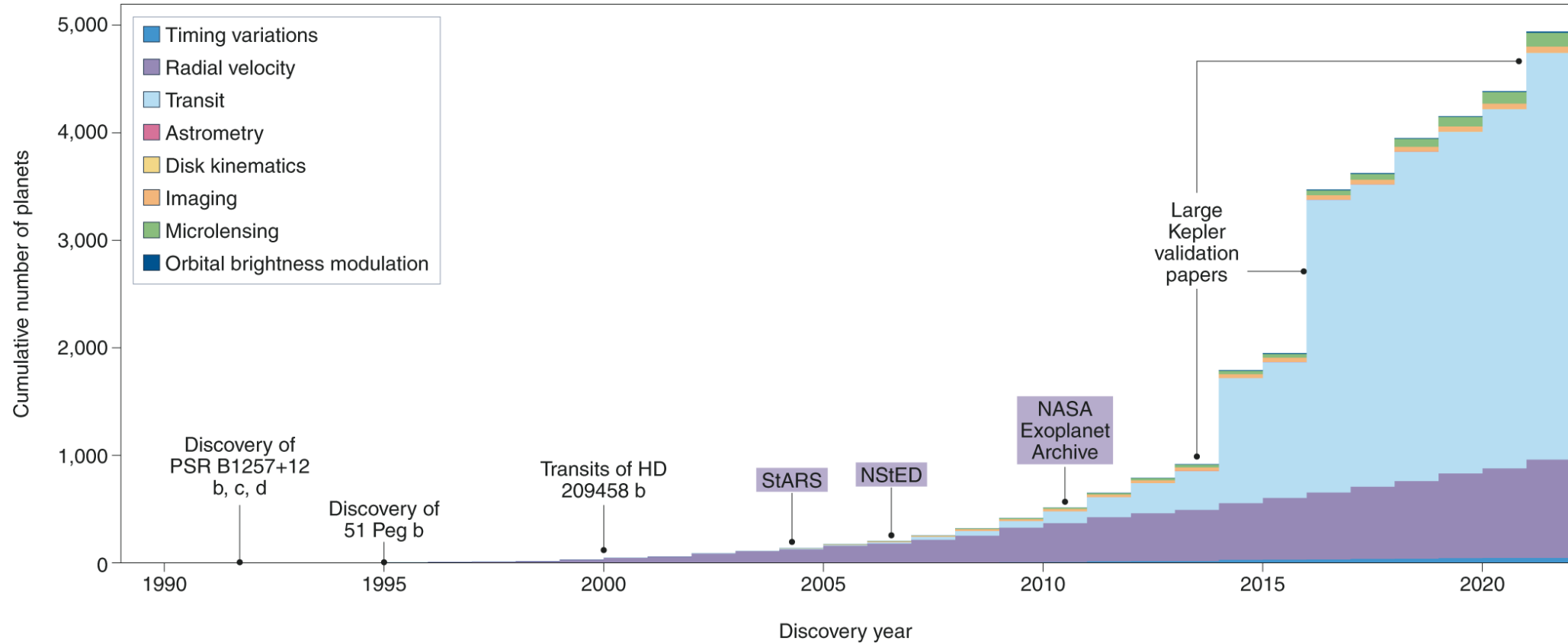


High-resolution spectroscopic time series for exoplanets' characterization

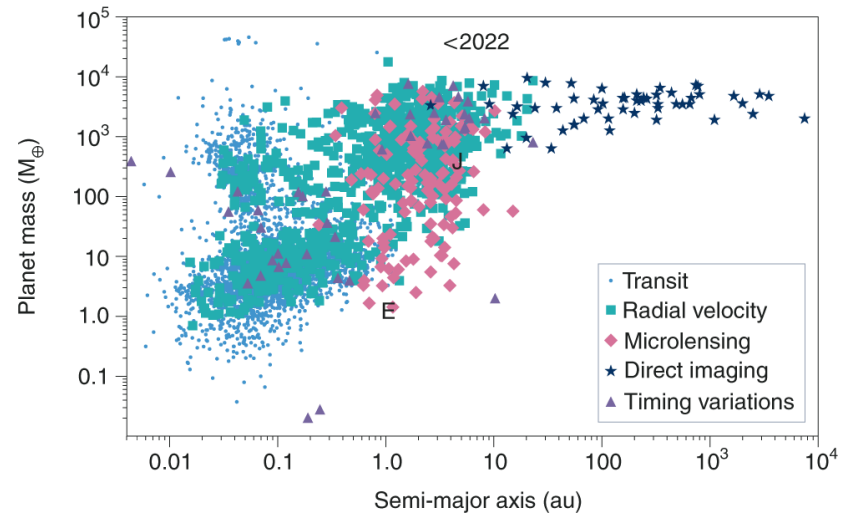
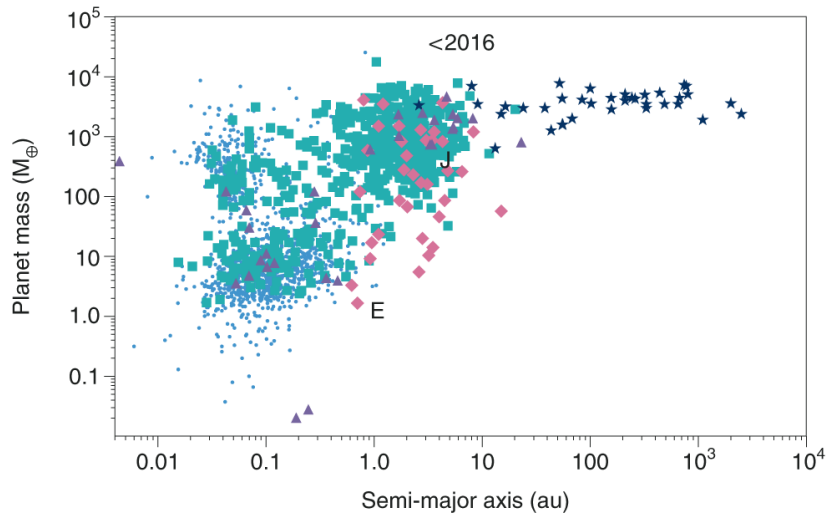
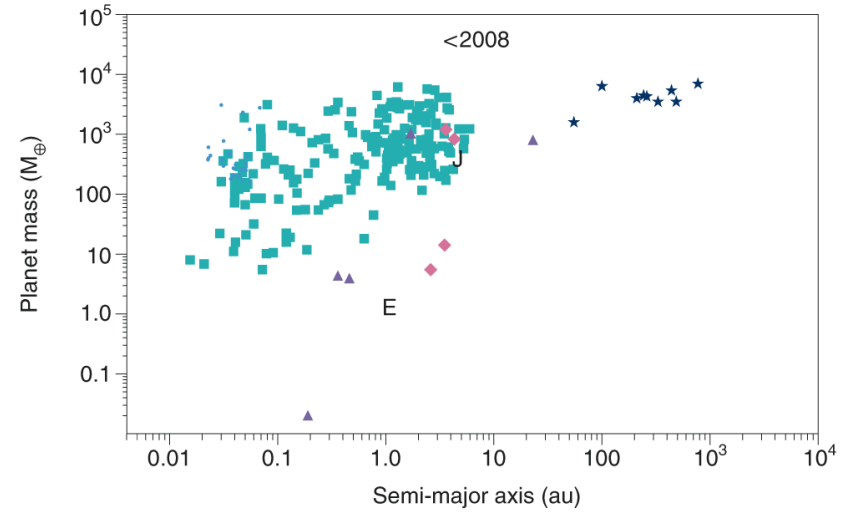
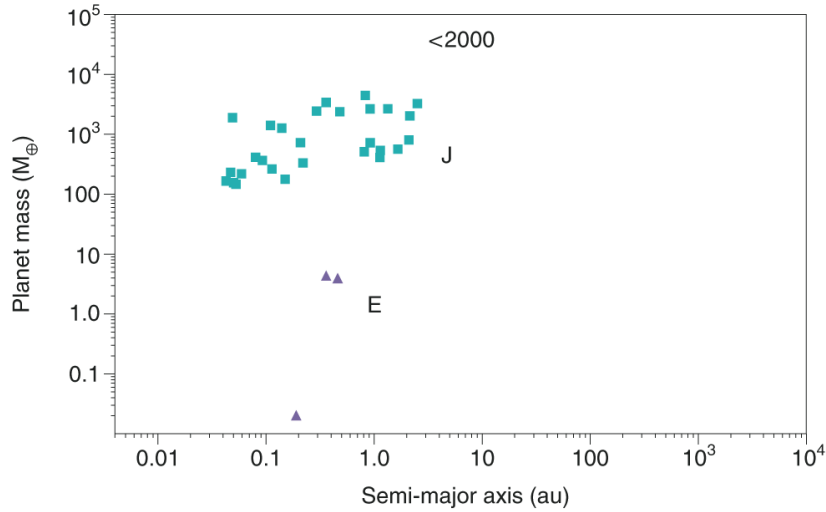
M. Rainer
INAF – OABrera



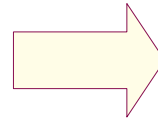
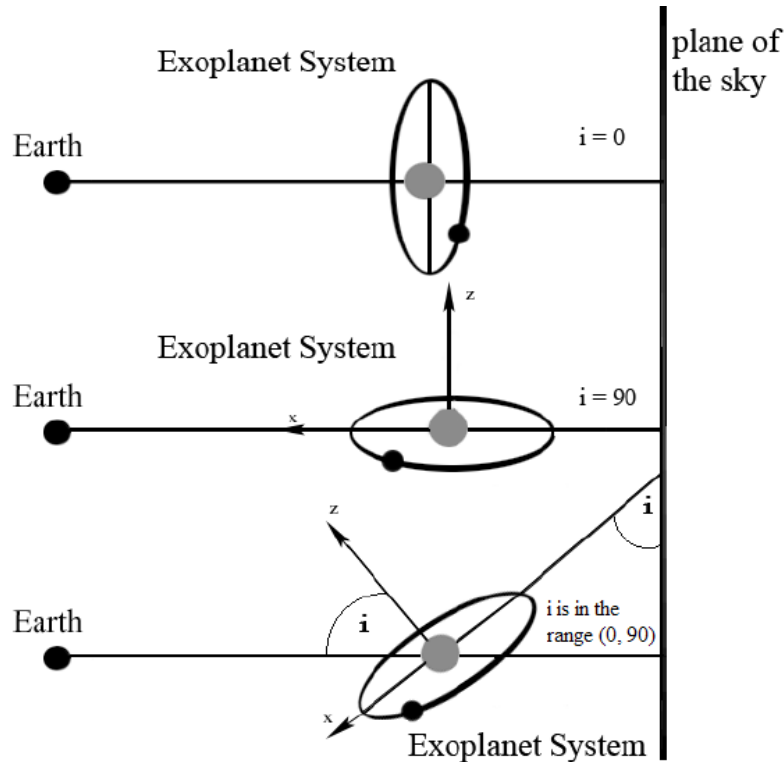
Planetary systems: discovery



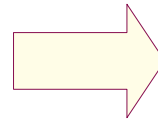
Planetary systems



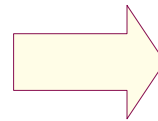
Inclination angle



Astrometry (e.g., Gaia)
Direct imaging



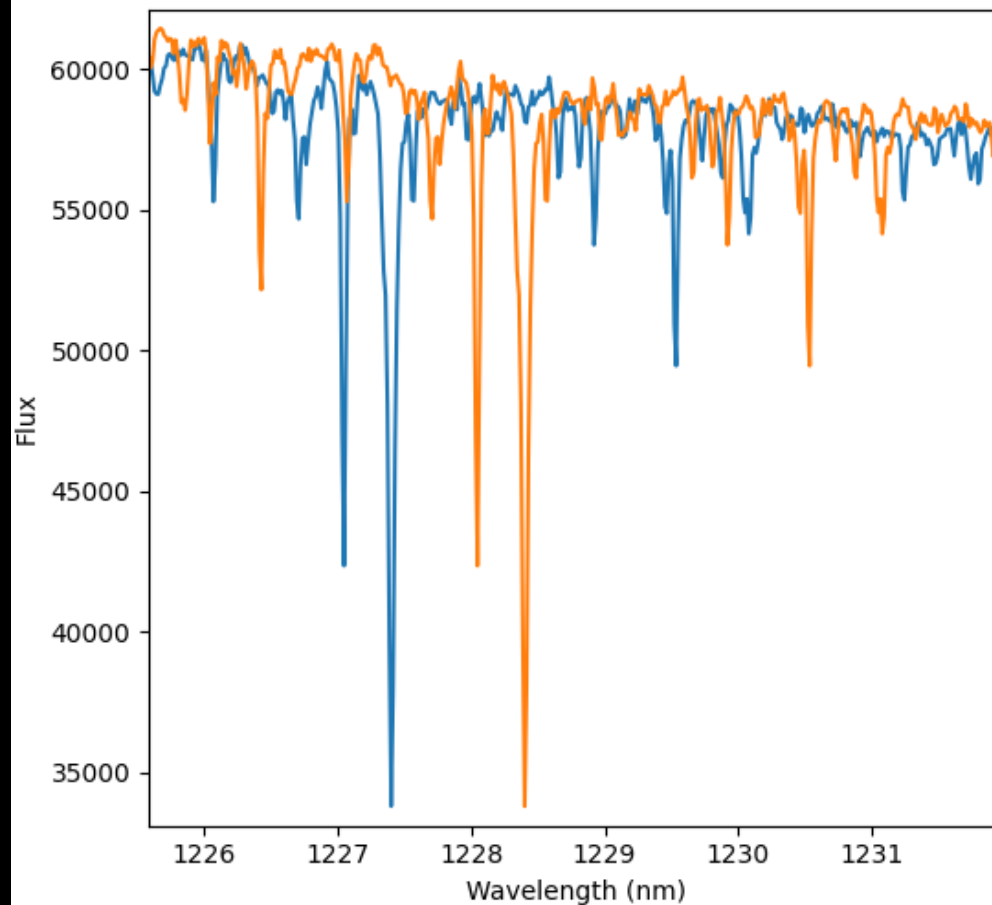
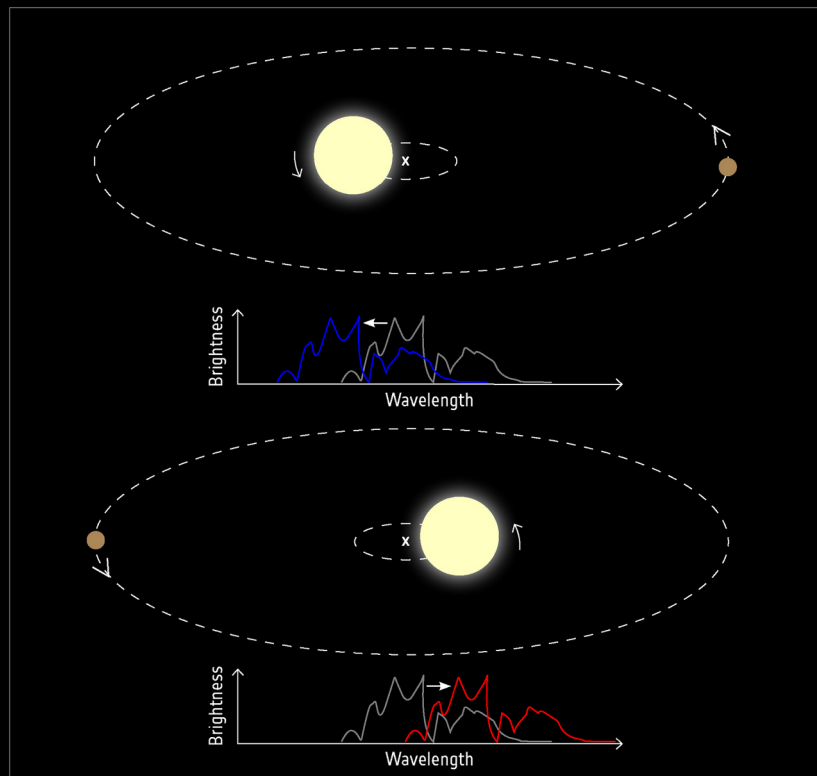
Transit (e.g., Kepler, TESS, Plato)
Radial velocity (ground-based)



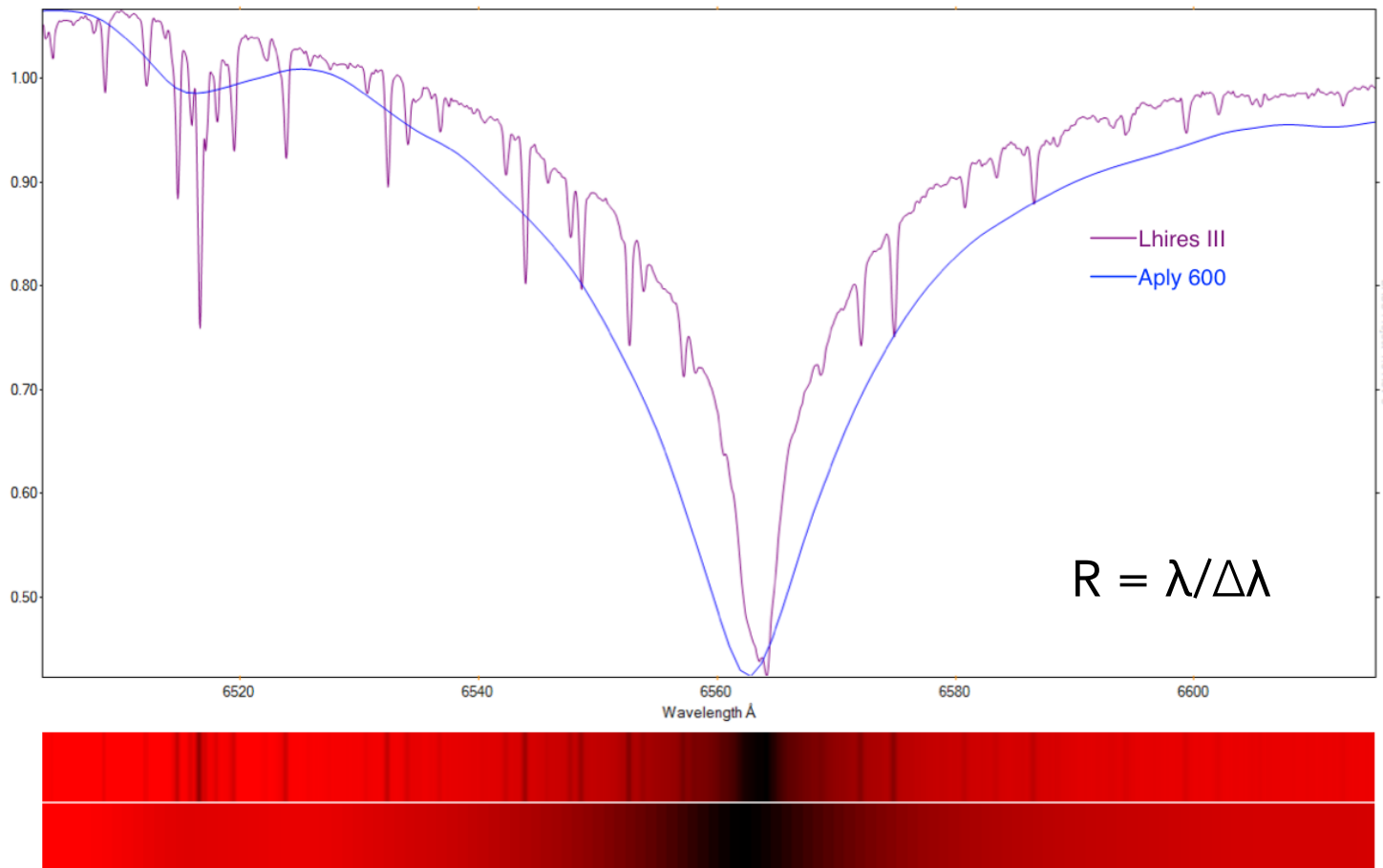
Radial velocity (ground-based)
Astrometry (e.g., Gaia)
Direct imaging

Radial velocity method

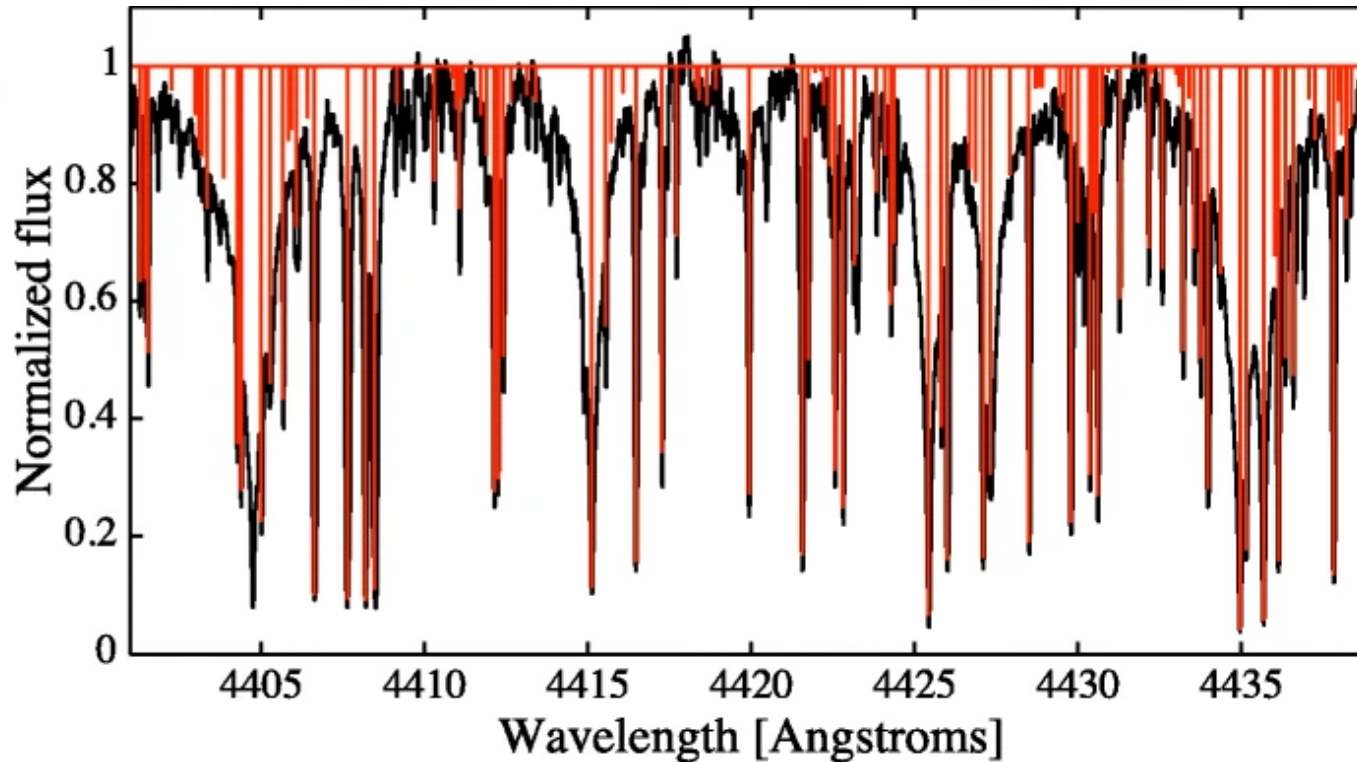
Radial velocity measurements



Radial velocity method: high-resolution

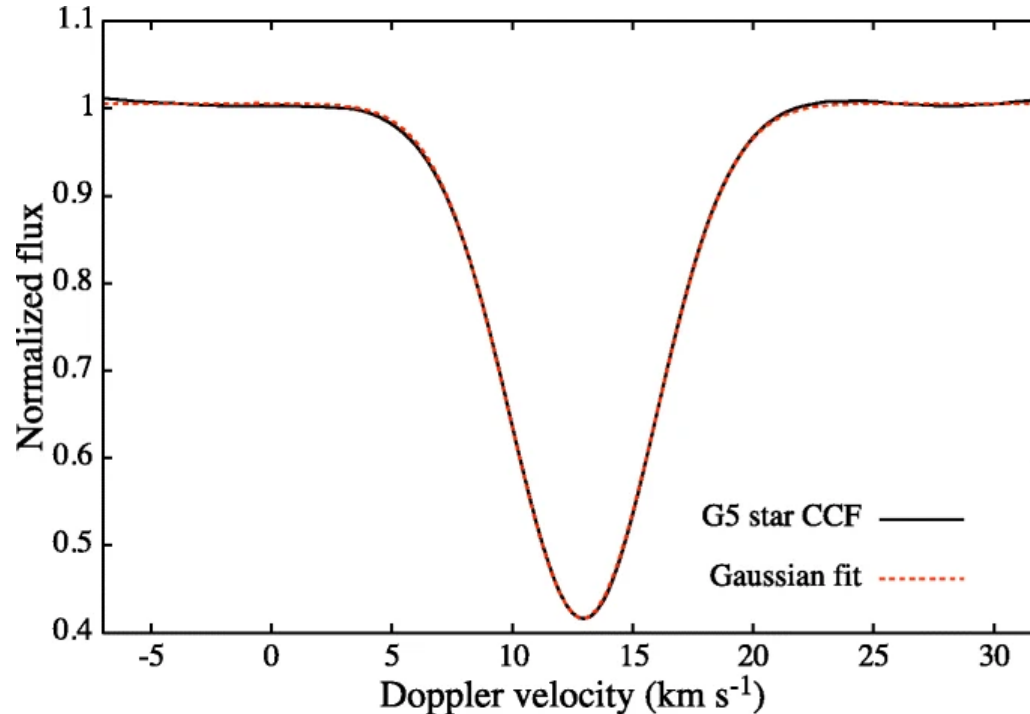


Radial velocity method: cross-correlation



S = normalized observed spectrum T = template (mask or model)

Radial velocity method: cross-correlation

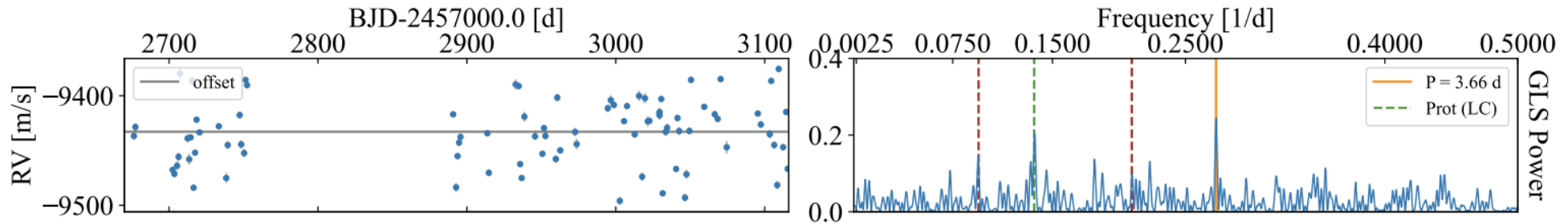


$$\text{CCF}(v) = \sum_i S_i \times T_{(i-v)}^*$$

$$\text{SNR}_{\text{CCF}} \approx \text{SNR}_S \times \sqrt{N_{\text{lines}}}$$

Radial velocity method: time-series

Mantovan, G., et al.: A&A, 682, A129 (2024)

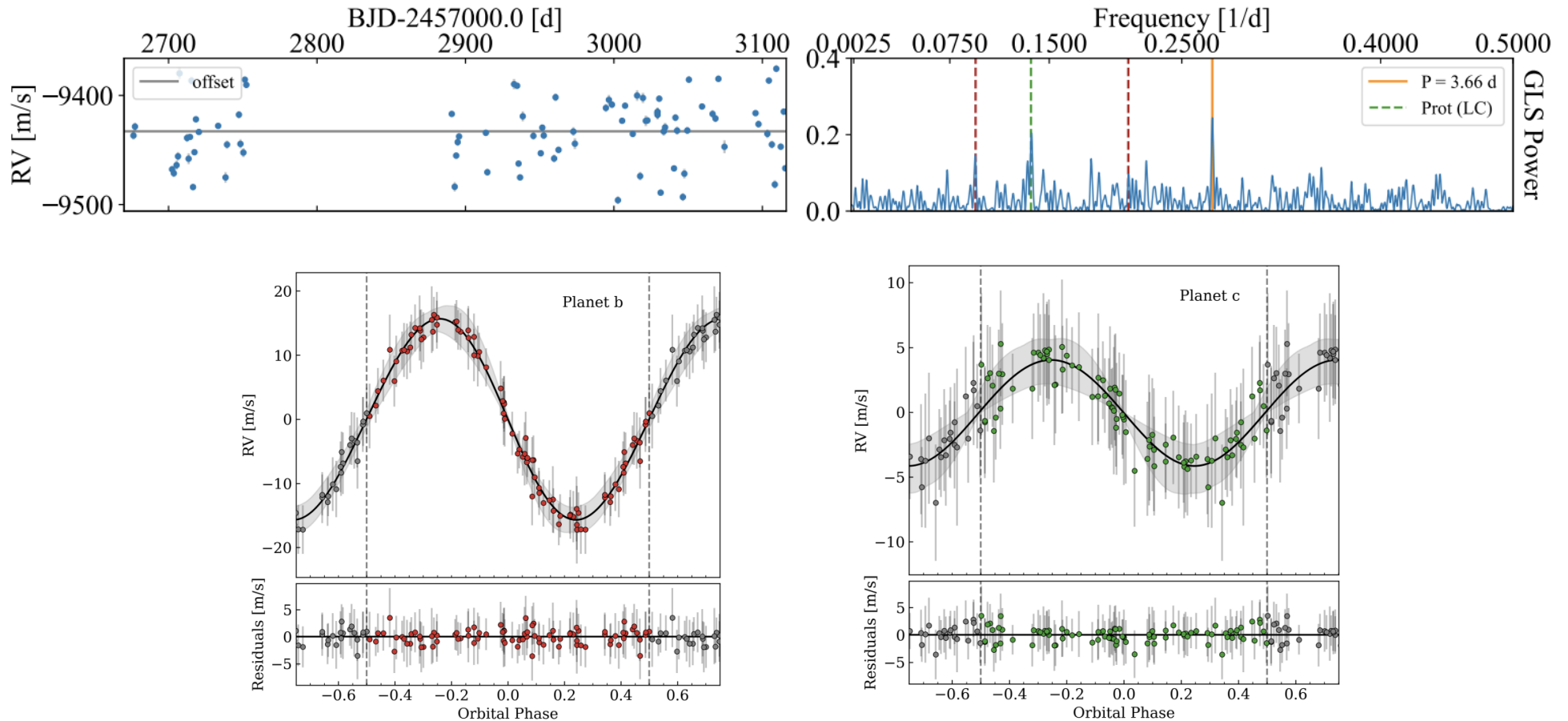


The main method used in exoplanet search to investigate the radial velocity time-series is the Lomb-Scargle algorithm, that allow us to detect and characterize periodic signal in non-uniformly sampled data.

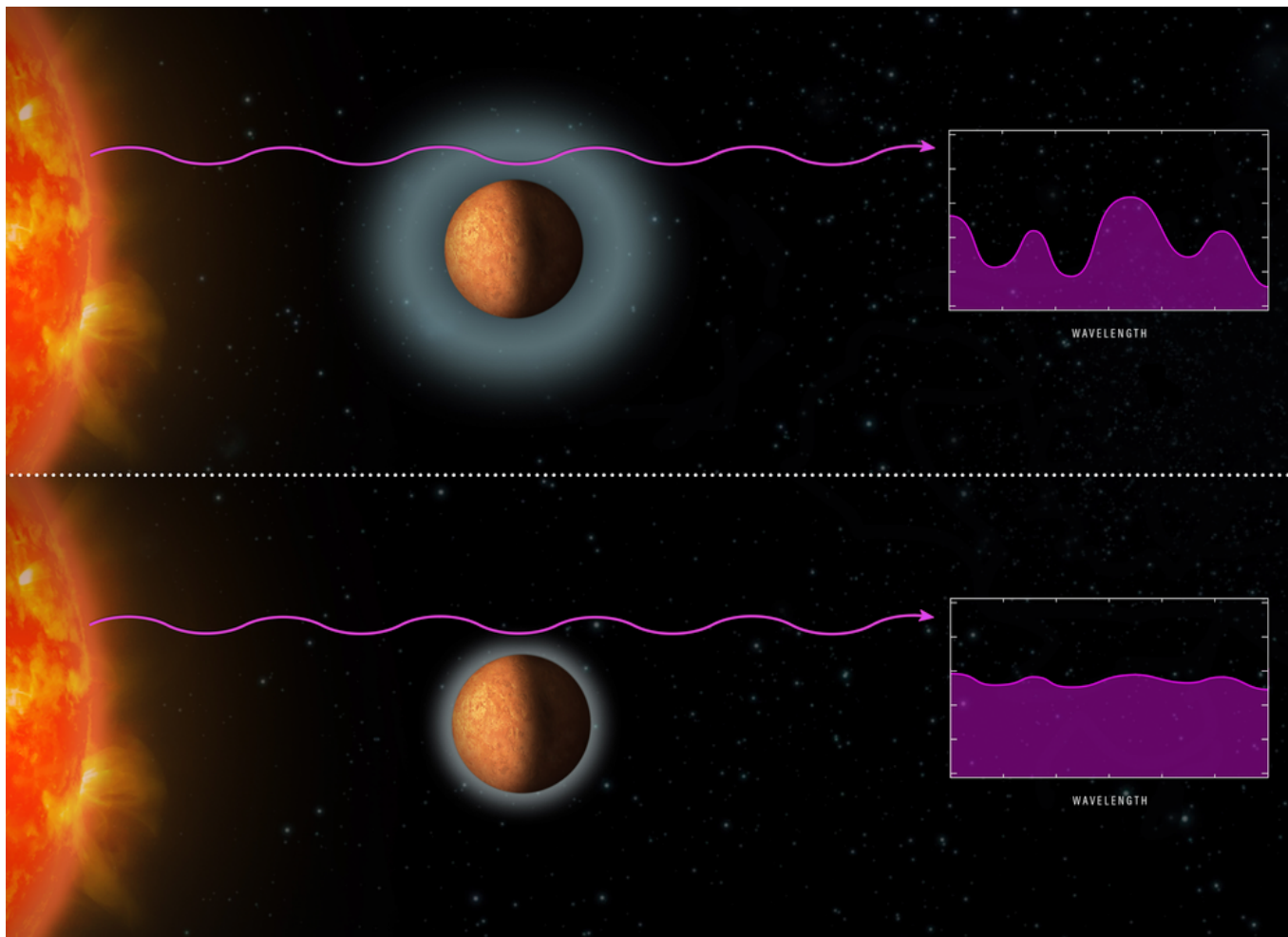
Understanding the Lomb-Scargle Periodogram, VanderPlas J.T., 2018 ApJ 236, 1
Least-Squares Frequency Analysis of Unequally Spaced Data, Lomb N.R., 1976, Ap&SS 39, 447
Studies in astronomical time series analysis. II. Statistical aspects of spectral analysis of unevenly spaced data, Scargle J.D., 1982, ApJ 263, 835

Radial velocity method: time-series

Mantovan, G., et al.: A&A, 682, A129 (2024)



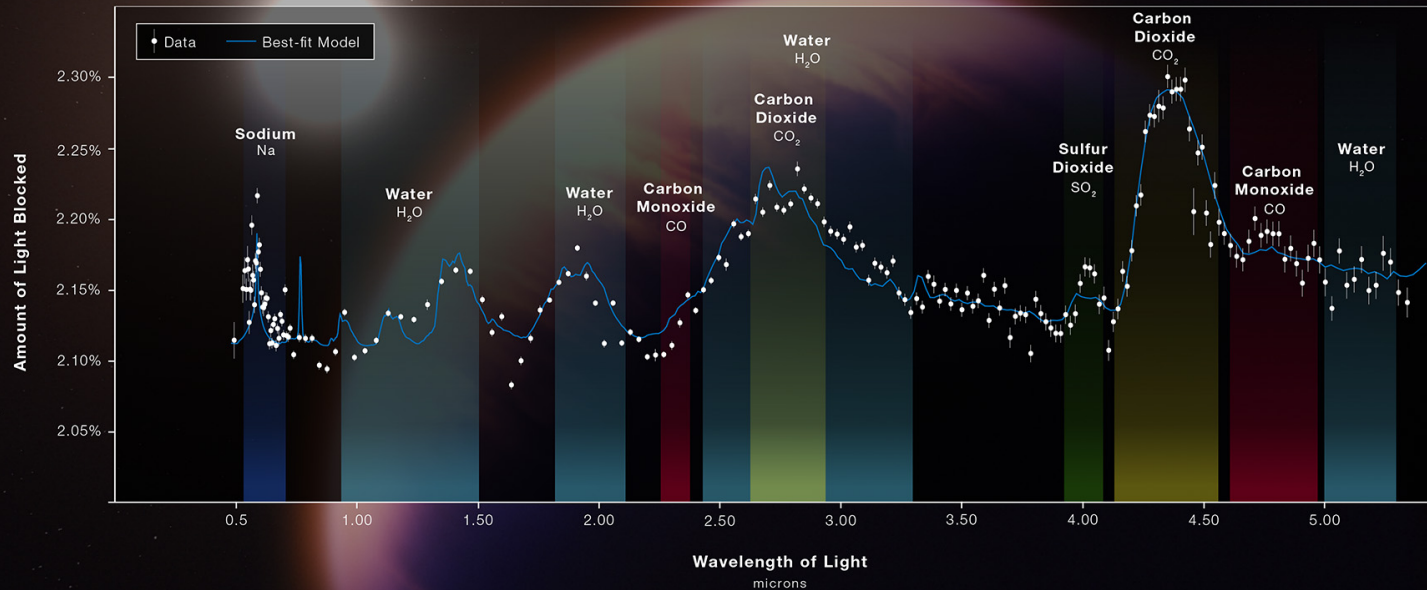
Transiting exoplanets



Low resolution spectroscopy

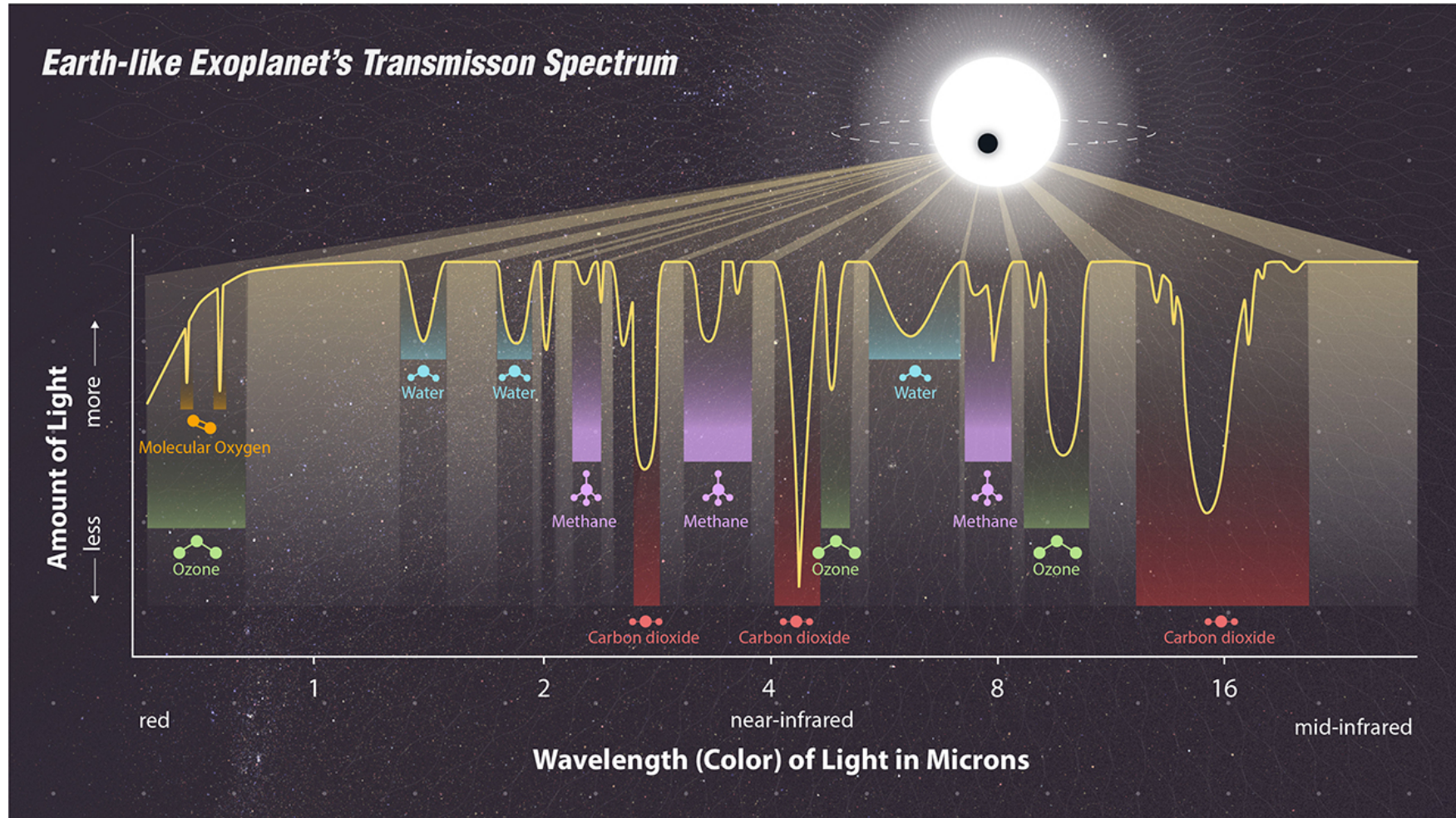
HOT GAS GIANT EXOPLANET WASP-39 b ATMOSPHERE COMPOSITION

NIRSpec PRISM

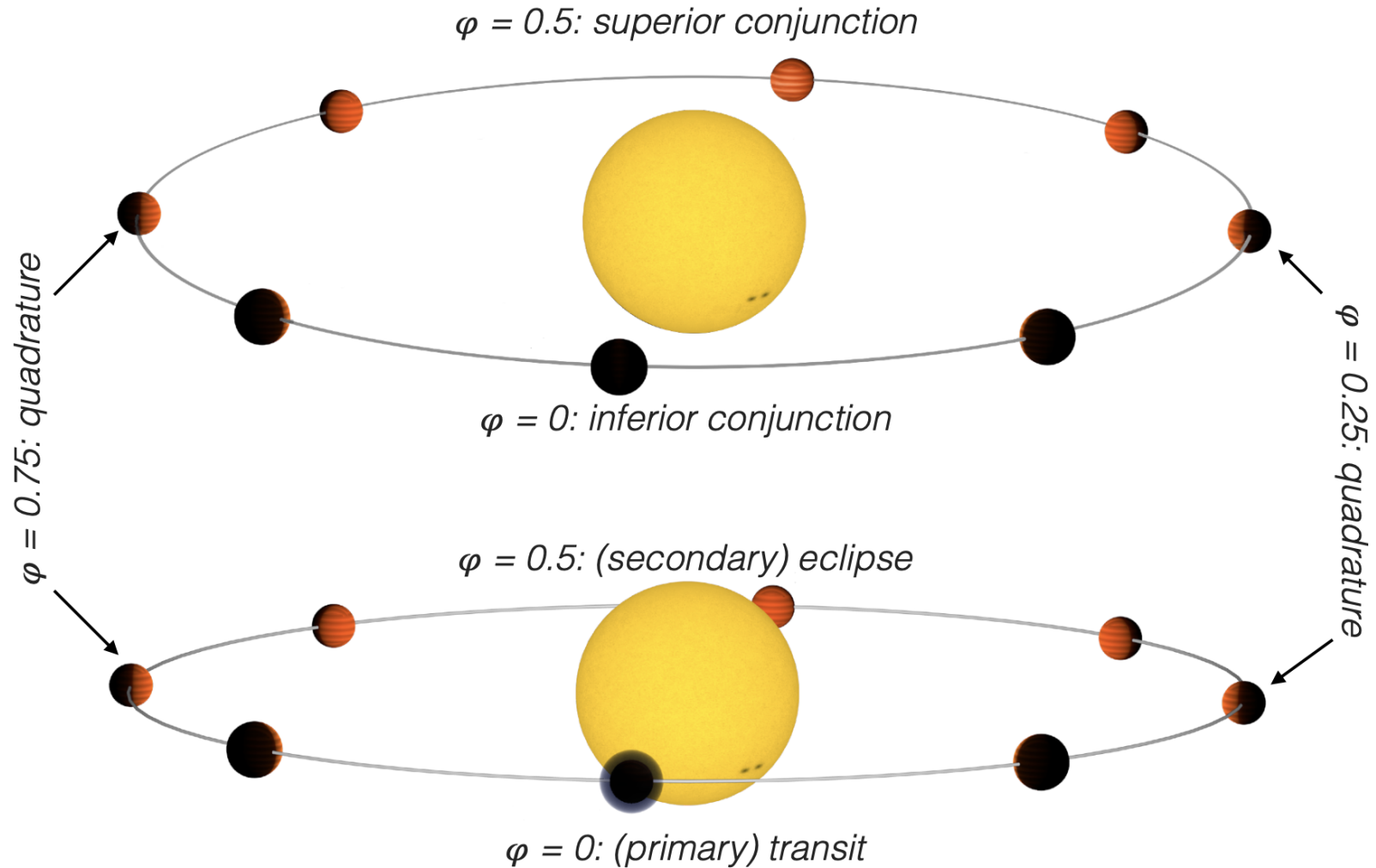


WEBB
SPACE TELESCOPE

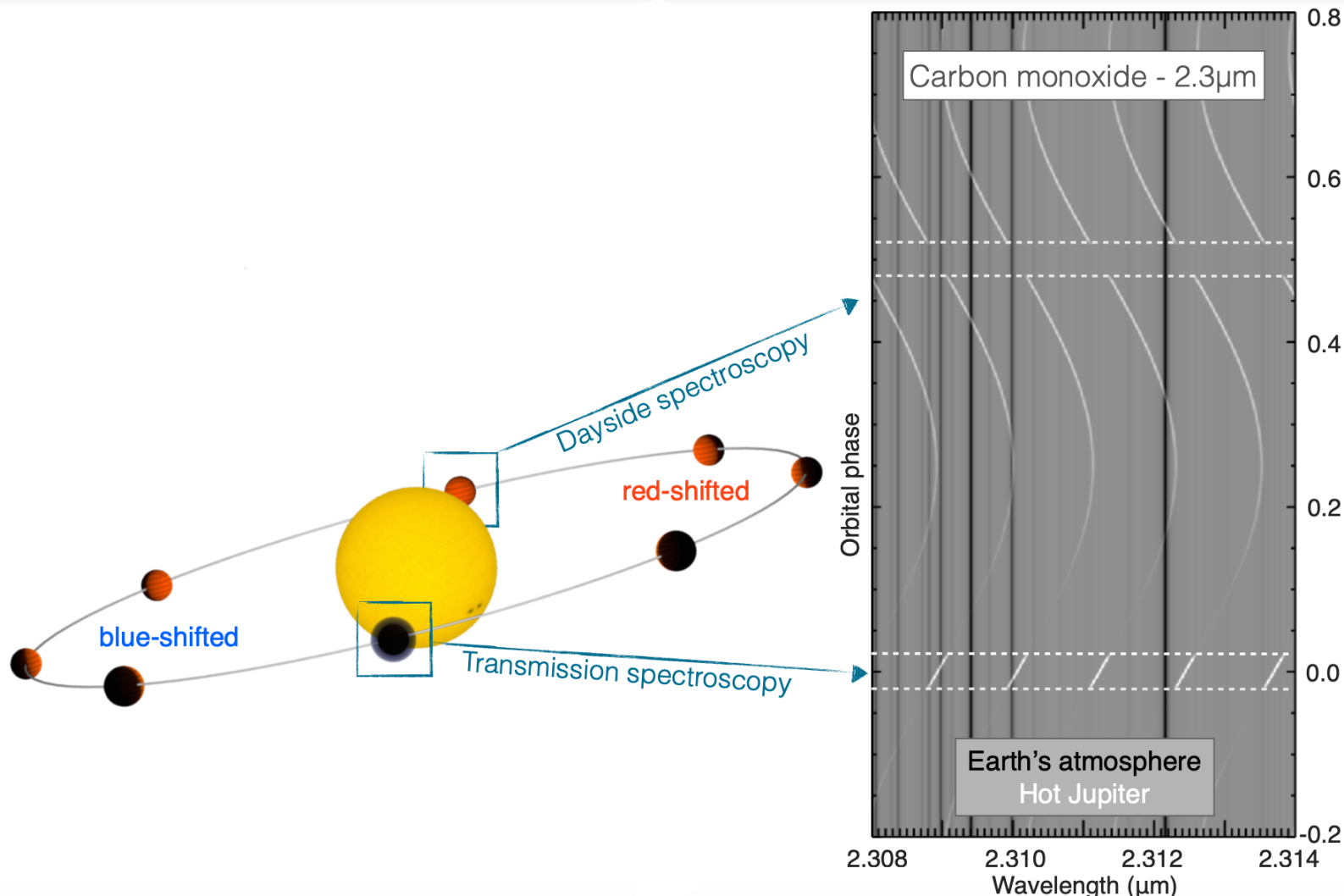
High resolution spectroscopy



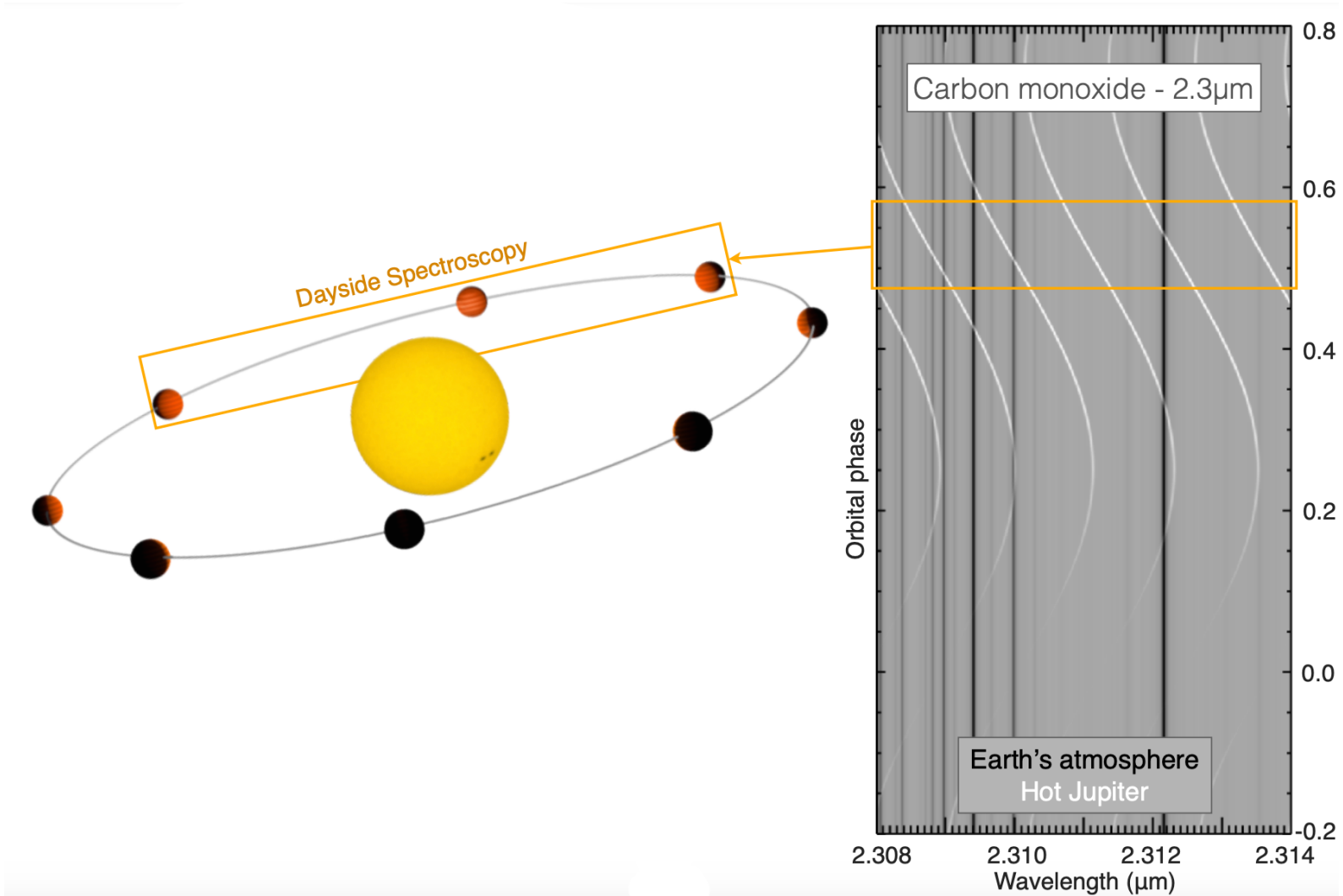
Planetary systems



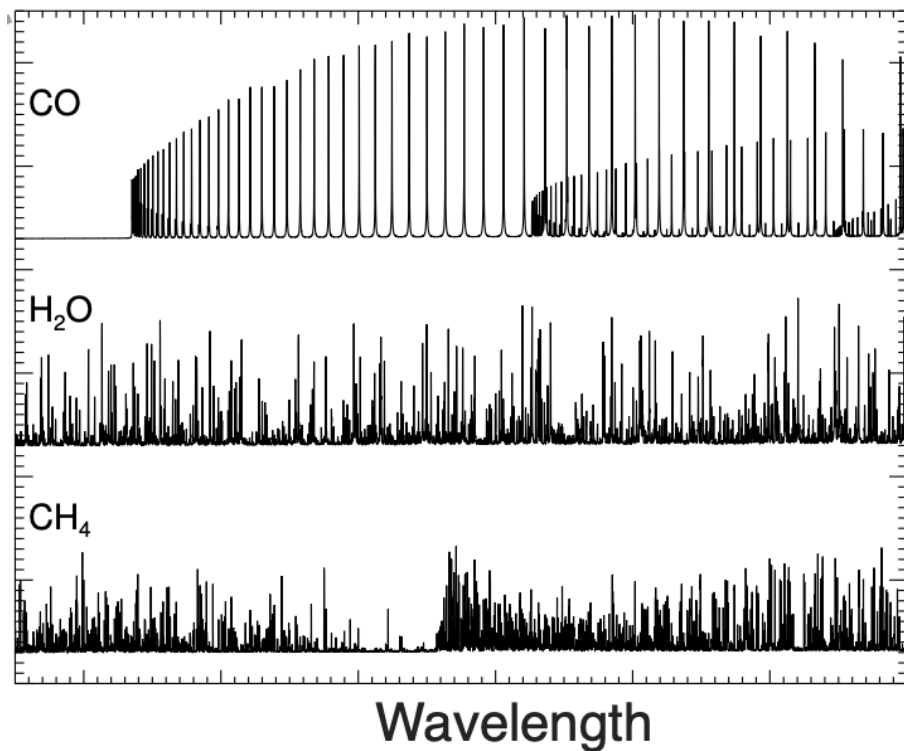
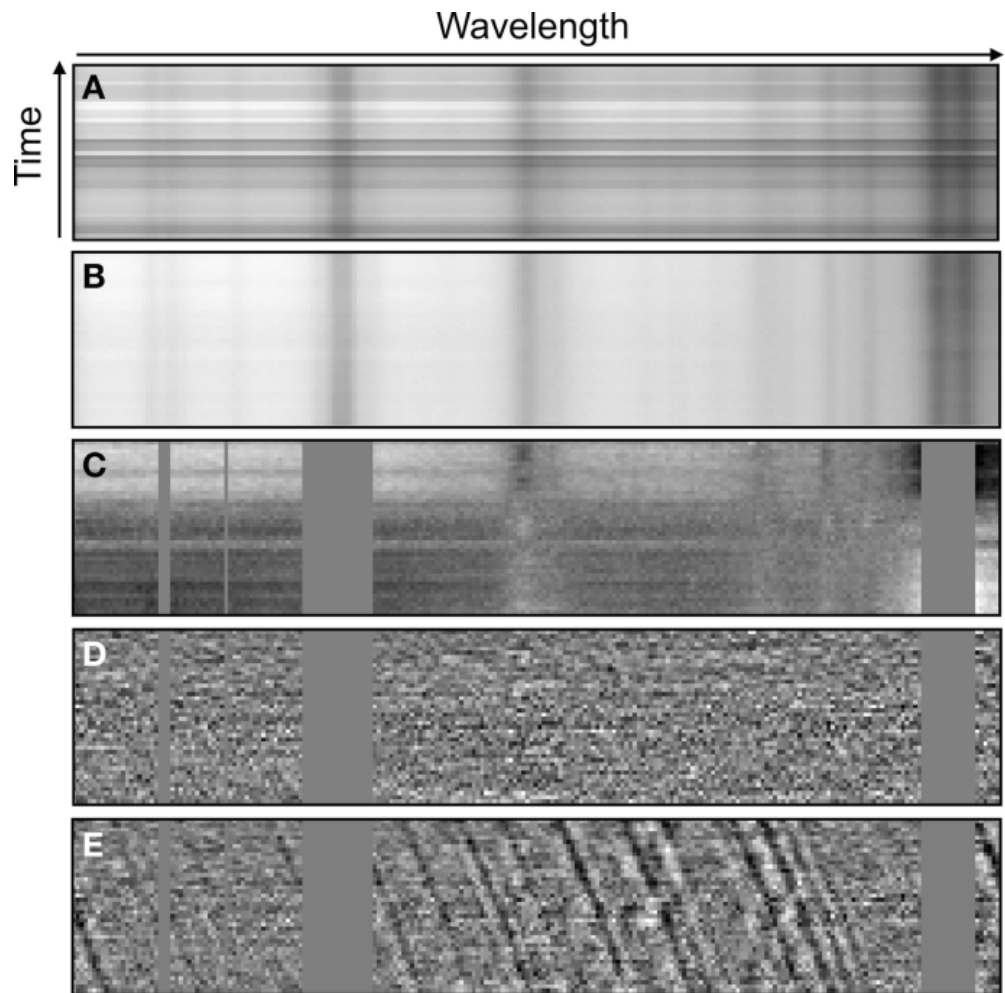
High resolution spectroscopy



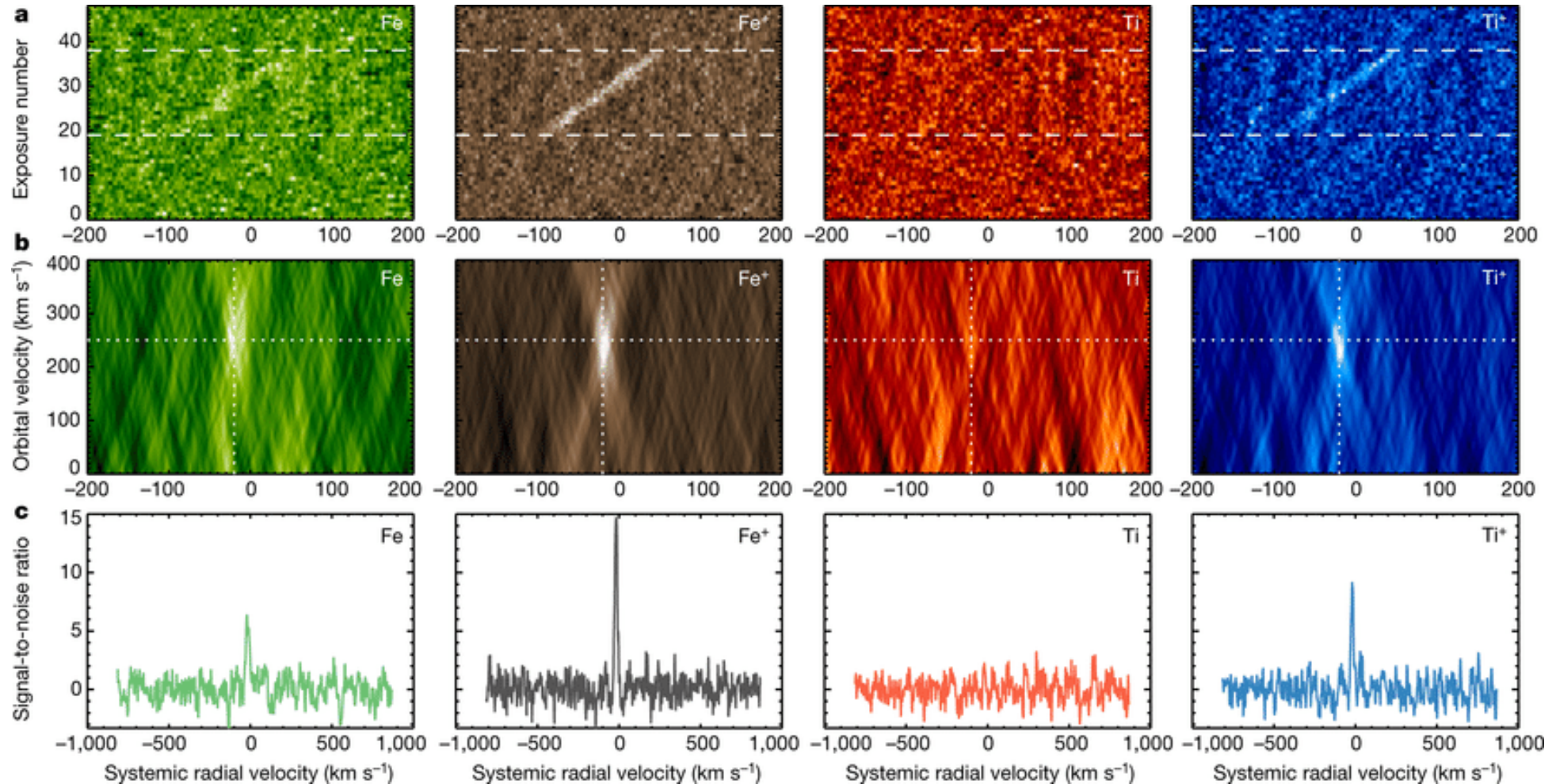
High resolution spectroscopy



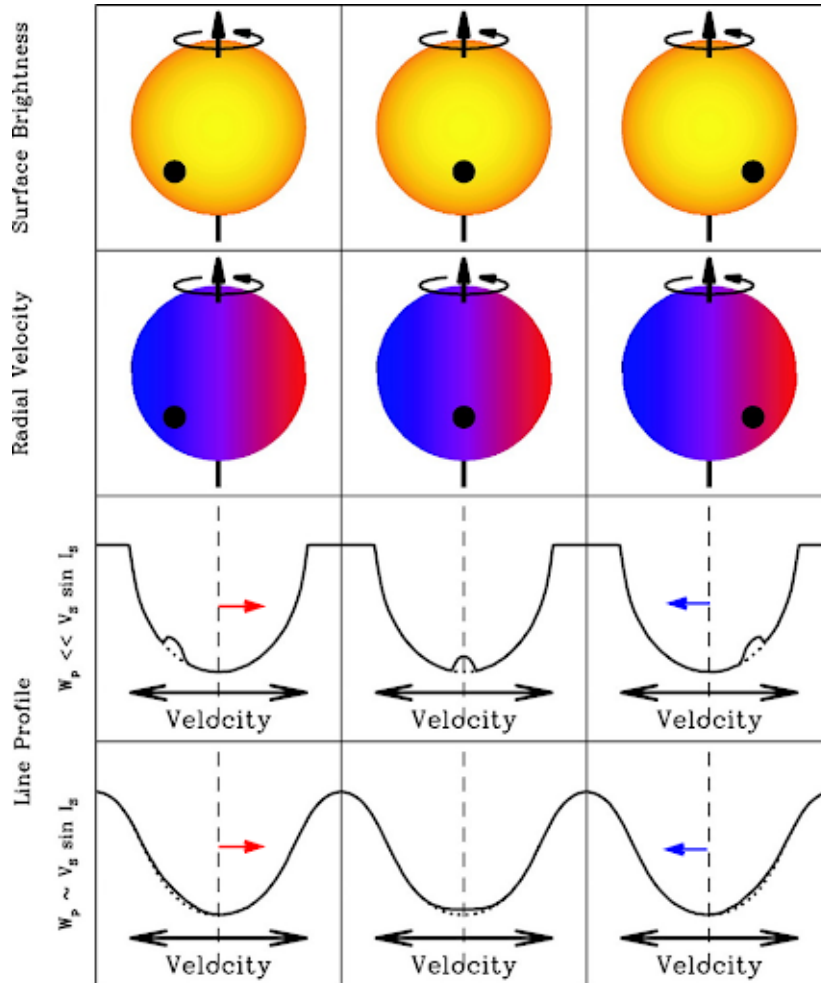
Cross-correlation with models



Cross-correlation with models



The Rossiter-McLaughlin Effect

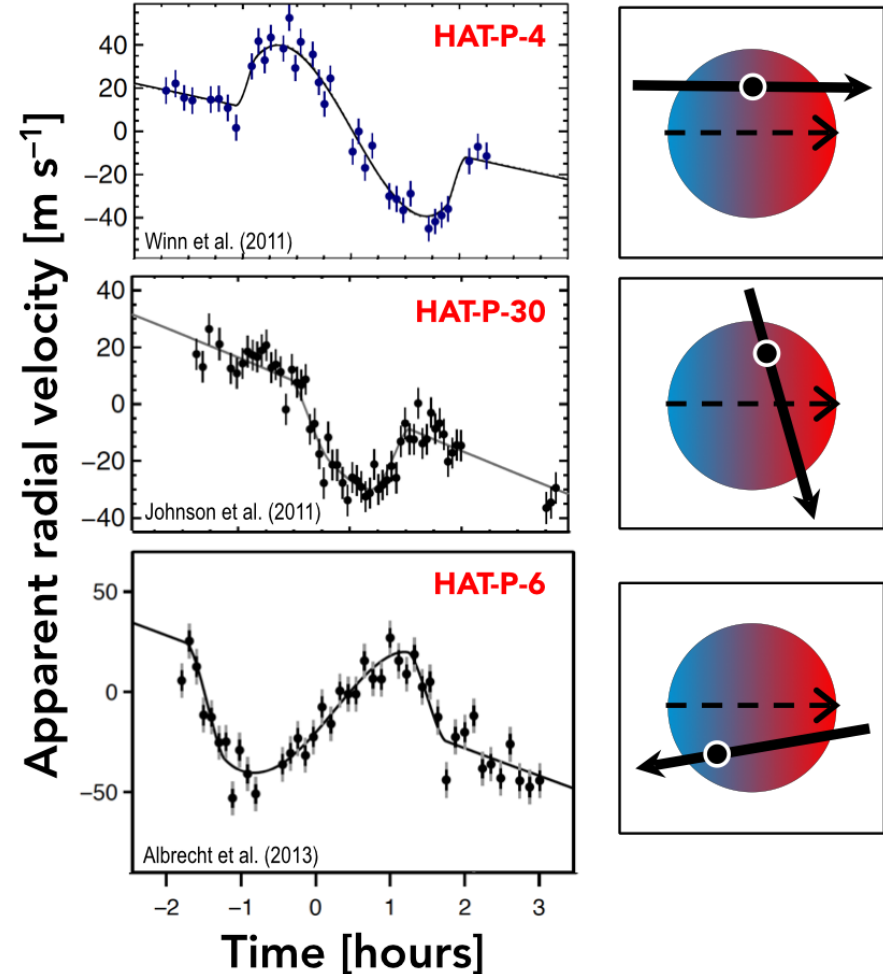
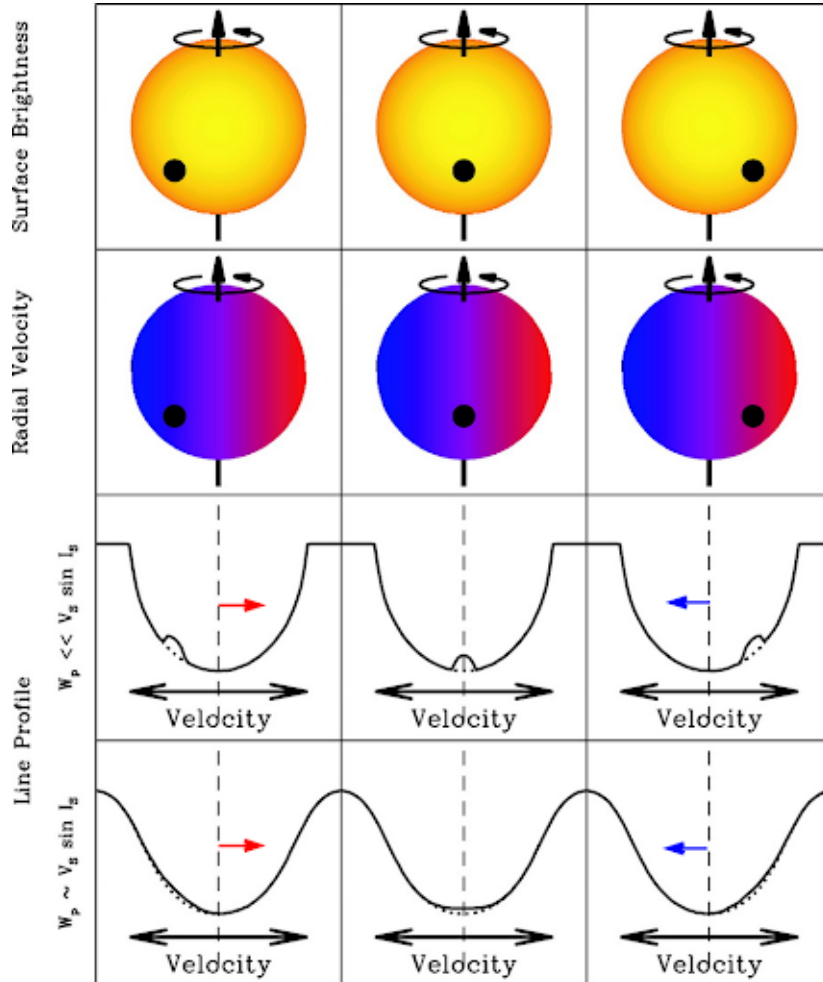


On the detection of an effect of rotation during eclipse in the velocity of the brighter component of beta Lyrae, and on the constancy of velocity of this system, Rossiter R.A., 1924, AJ 60, 15

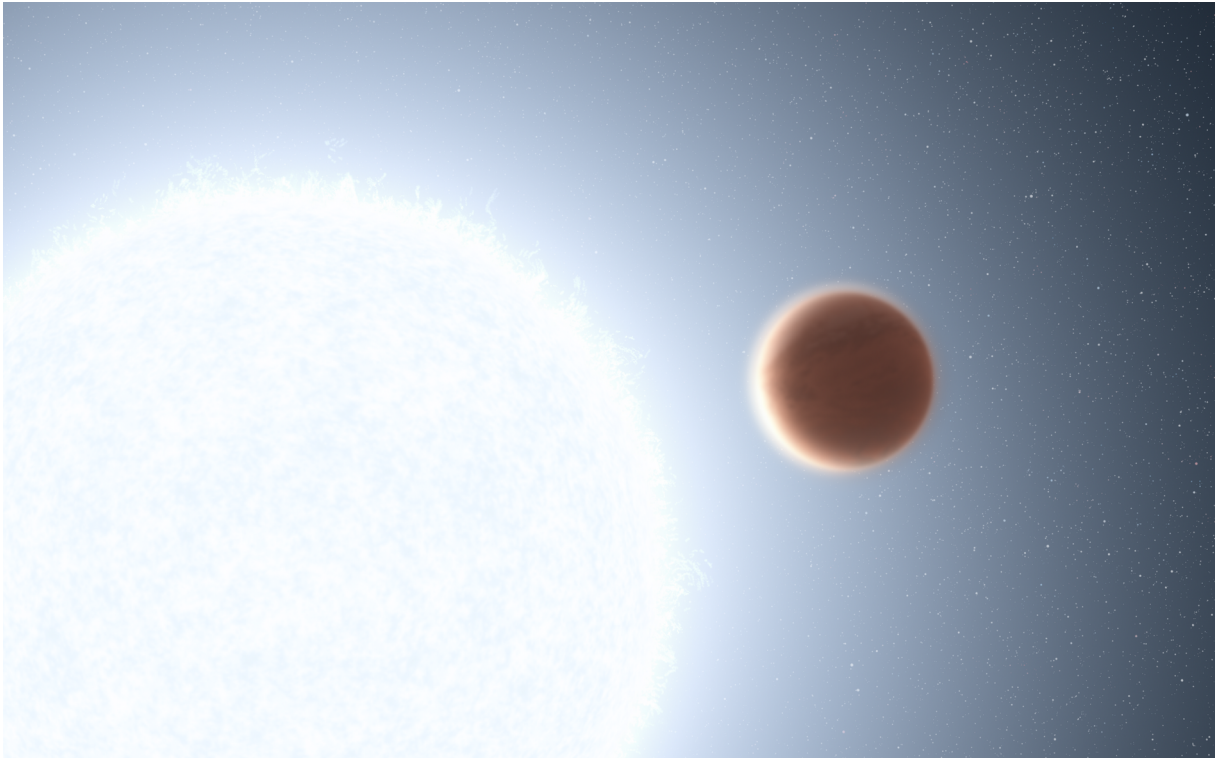
Some results of a spectrographic study of the Algol system, McLaughlin D.B., 1924, AJ 60, 22

The Rossiter-McLaughlin Effect and Analytic Radial Velocity Curves for Transiting Extrasolar Planetary Systems, Ohta Y., et al., 2005, ApJ 622, 1118

The Rossiter-McLaughlin Effect

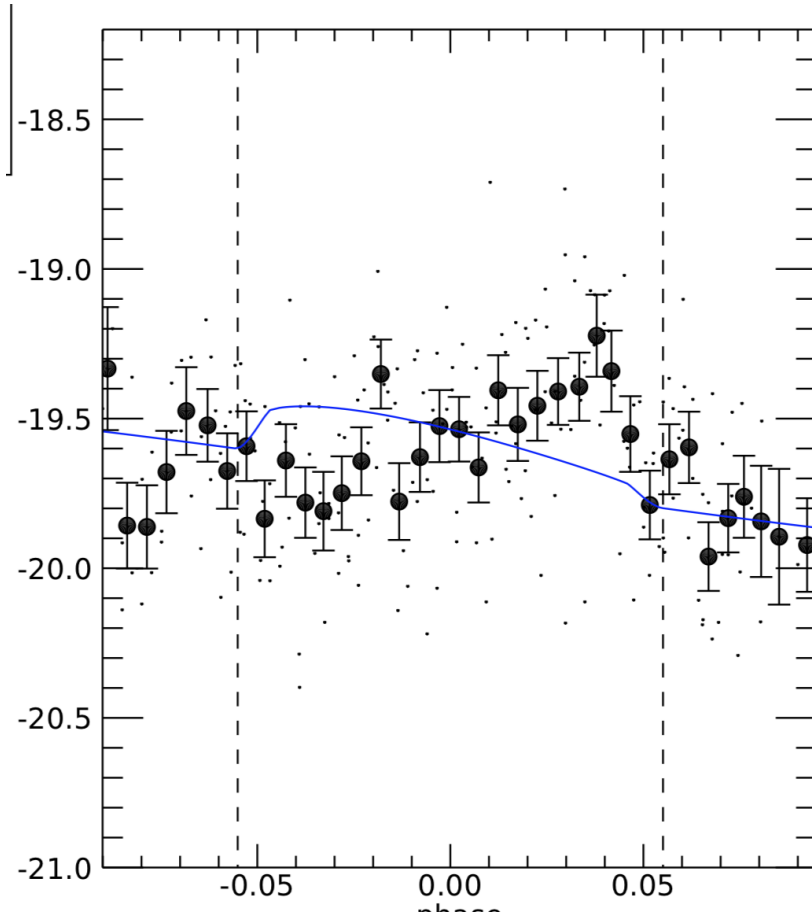


Ultra-Hot Jupiters



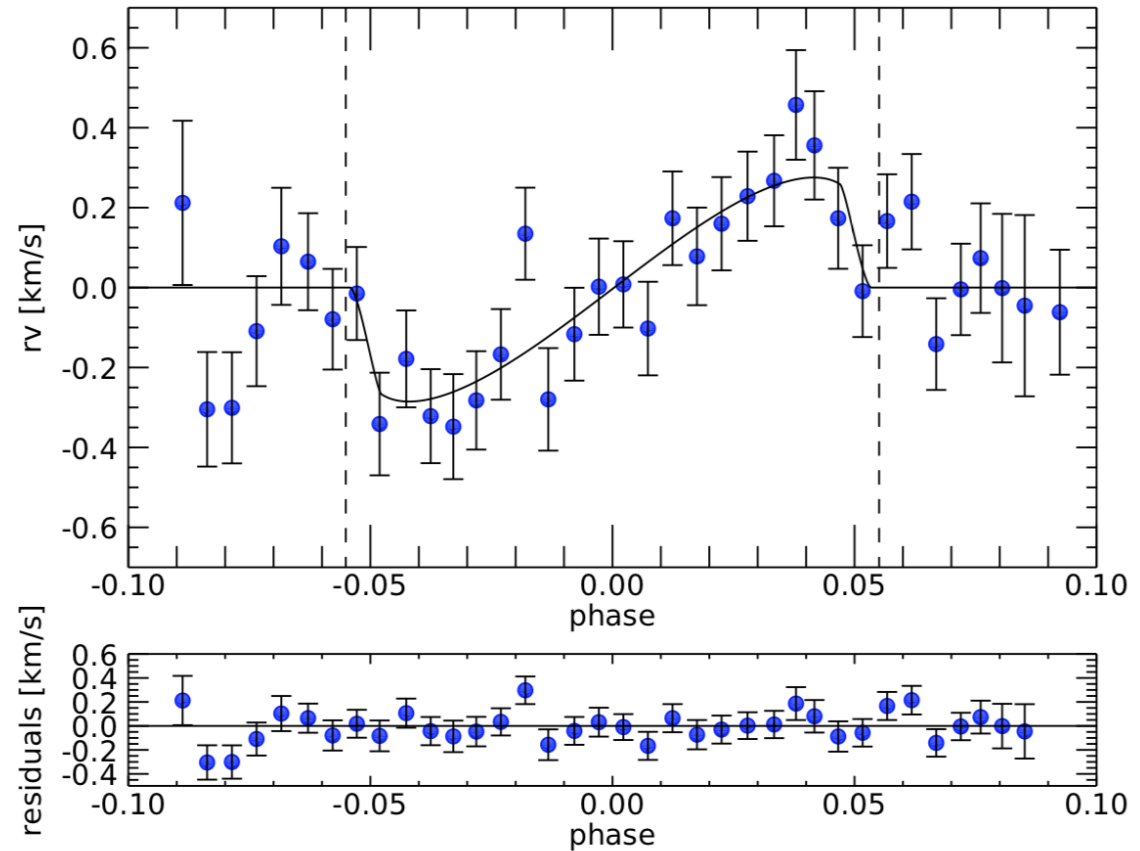
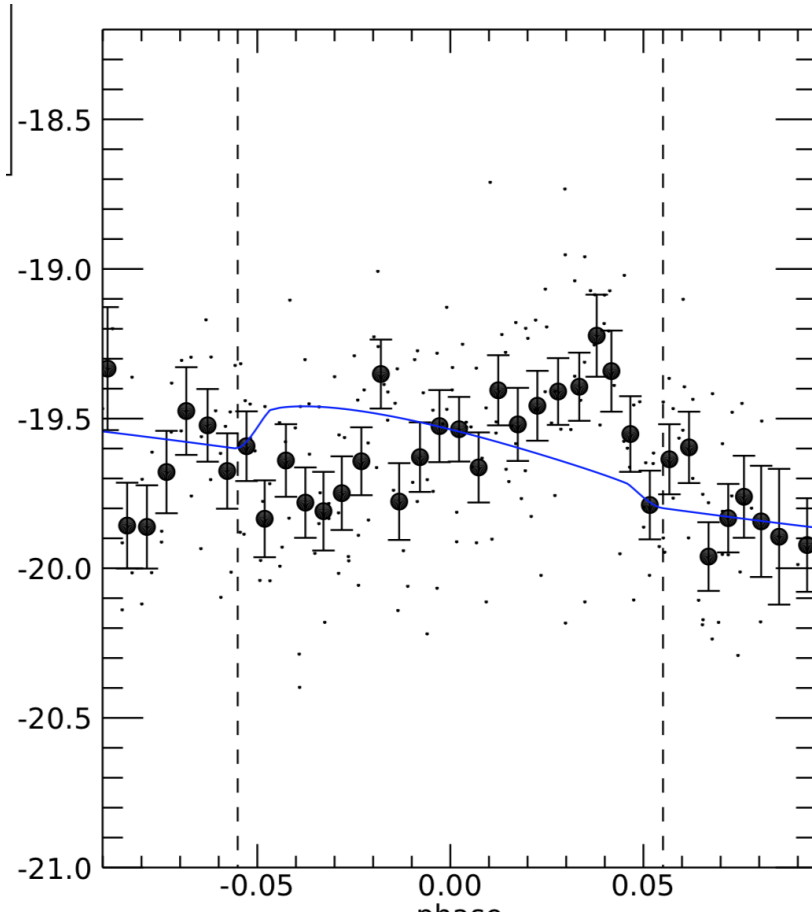
Ultra-Hot Jupiters (UHJ) orbit around hot A-type stars, and they have an equilibrium temperature larger than 2000-2200 K: neutral and ionized iron is present in their atmospheres.

The atmospheric Rossiter-McLaughlin Effect



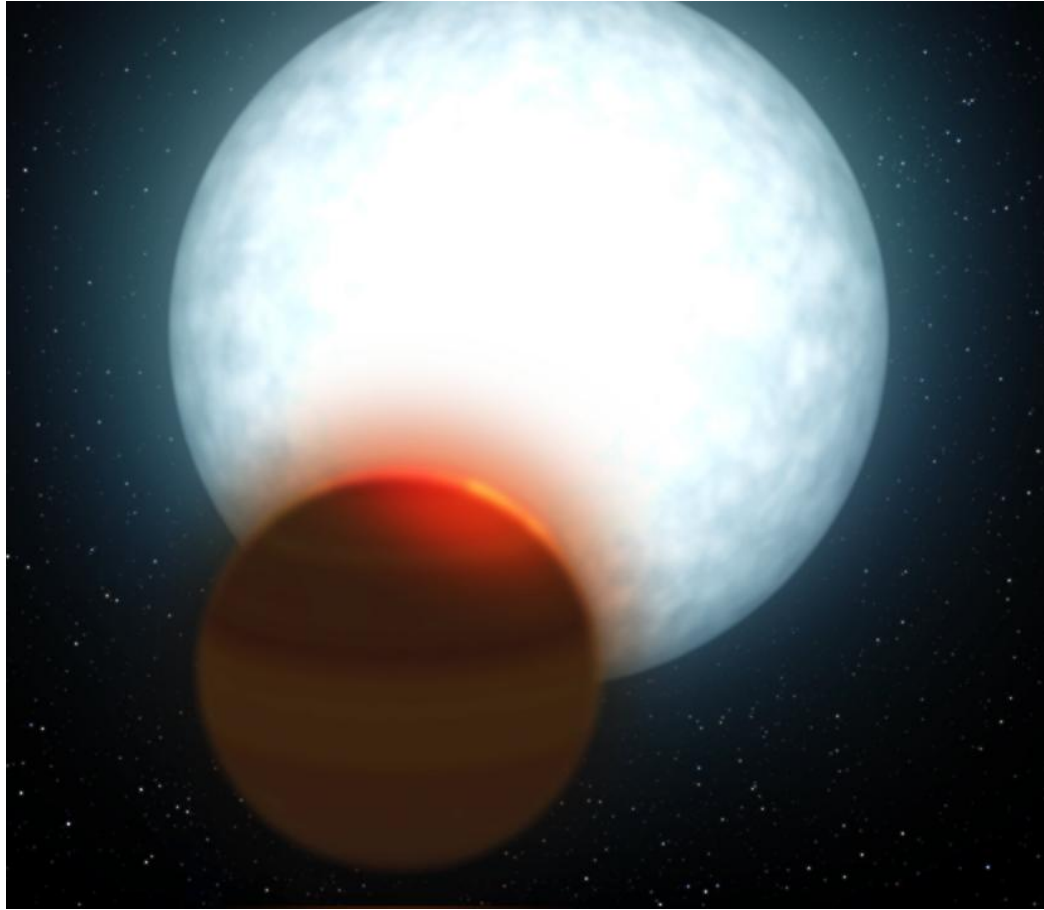
KELT-9b, see Borsa F., et al., 2019, A&A 631, 34

The atmospheric Rossiter-McLaughlin Effect



KELT-9b, see Borsa F., et al., 2019, A&A 631, 34

KELT-20b



KELT-20 (star)

Spectral type: A2

$T_{\text{eff}} = 8980 \pm 130 \text{ K}$

$m_V = 7.6$

KELT-20b (planet)

$M < 3.51 M_J$

$R = 1.83 R_J$

$T_{\text{eq}} = 2260 \pm 50 \text{ K}$

Period = 3.474119 days