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FIOS: Fabry Perot Instrument for Oxygen Searches in Exoplanet Atmospheres

Surangkhana Rukdee(1), Sagi Ben-Ami(1), Mercedes López-Morales(1), Juliana Garcia-Mejia(1), David Charbonneau(1), and Andrew Szentgyorgyi(1)
(1) Center for Astrophysics | Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA
(surangkhana.rukdee@cfa.harvard.edu)

Abstract

The upcoming Extremely Large Telescopes are expected to have enough collecting area to start searching for potential biosignature gases, notably molecular oxygen (O_2), in the atmospheres of small planets around nearby stars [4, 8]. Recent simulations have shown that spectral resolutions of 300,000 - 400,000 are optimal to detect O_2 in the atmosphere of an earth analog. Typical high resolution spectrographs have resolutions around 100,000. In order to increase detection capabilities, we have developed FIOS[1], a Fabry Perot interferometer array coupled to a high resolution spectrograph. FIOS can achieve a spectral resolution of 500,000 at the O_2 A-band (760 nm). It is optimal for O_2 detection, while maintaining a higher throughput compared to instruments with similar spectral resolving power. We describe the instrument concept, a simulation of its sensitivity, and preliminary results from our lab prototype.

1. Introduction

Transmission spectroscopy is an observational method to unveil the chemical composition of an exoplanet atmosphere as a planet transits its host [2, 6]. This technique can be used to search for bio-signature gases to indicate habitability of an alien world, in particular the simultaneous detection of O_2, together with CH_4 or N_2O [5, 7]. [3, 4] demonstrated that to fully resolve the individual molecular oxygen absorption lines requires a high spectral resolution, R = 300,000 to 400,000. [1] suggested this can be achieved by using a unique array of Fabry Perot Interferometers upstream of a typical high resolution spectrograph like for example the GMT-Consortium Large Earth Finder (G-CLEF)[9] currently being built for the Giant Magellan Telescope (GMT) .

2. Prototype

In this study, we implement a two-etalon prototype of the Fabry Perot Interferometer array presented in [1], optimized for the oxygen A-band. We aim to demonstrate that the expected resolution and the instrument efficiency can be achieved.

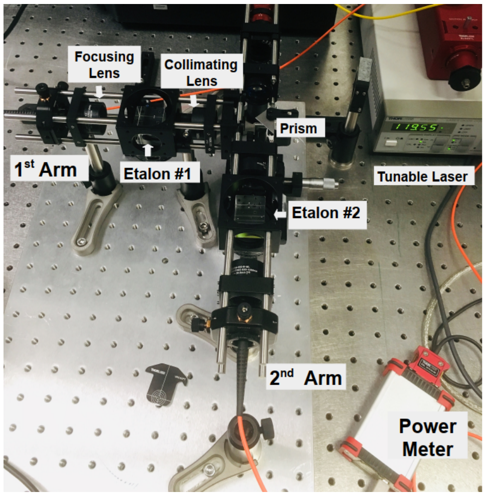

Figure 1: The FIOS prototype setup consisting of two arms containing an etalon in each.

Figure 1 shows our implementation of the two-etalon array. The light from a tunable laser is collimated and focused onto a knife-edge prism, the beam is reflected into the first arm (to the left), which consists of a collimating lens, an etalon and a focusing lens. Wavelengths that satisfy the etalon phase condition, are transmitted, while other wavelengths are reflected towards the prism second reflective facet and go into a second arm with an identical setup. We place a photodiode sensor, which connects to a power-meter,

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[1] A Fabry perot Interferometer for Oxygen Searches (FIOS)

at the image plane of each arm and obtain the data from both arms simultaneously. We measure the output signal in narrow wavelength ranges by stepping through wavelength space at 1.5 pm intervals. The etalons differ in thickness, which cause the transmission peak to differ by R = 500,000. The angle of incidence is identical for both etalons.

3. Results

To analyse the data, we use the transmission model from [10]

$$I_T = \frac{T^2}{(1-R)^2(1+F\sin^2(\frac{\phi}{2}))} \qquad (1)$$

where T and R are the surface intensity transmission and reflection coefficients, respectively. The finesse F is defined as $F = \frac{4R}{(1-R)^2}$. The phase lag $\phi = \frac{2\pi}{\lambda}2dn_\lambda \cos\theta$ is the phase difference introduced by the optical delay for successive reflections, and it depends on the separation of the reflective surfaces d of the etalons, the wavelength dependent refractive index n_λ, and the angle of incidence θ of the light. In our model, we include the measured value R and assume no surface absorption.

Figure 2 shows the data obtained from the setup. Blue is the signal from the first arm and orange is from the second arm. We apply a χ^2 fit to the model in equation 1 for the parameters θ, R(reflectivity), d, and λ. Our initial parameters are based on the measurement. We follow [10] to account for various effects such as plate imperfections, finite dispersion of the input beam by assigning a Gaussian window, $w(n) = e^{-\frac{1}{2}(\frac{n}{\sigma})^2}$, and convolve the transmission signal to obtain a more realistic fit from the system defects.

4. Conclusion

We presented preliminary results from a Fabry Perot based prototype instrument for characterizing exoplanet atmospheres. This prototype yields an extreme high resolving power (R) approximately $500,000$ and a maximum throughput of 80%. In the near future, we plan to employ Dualons in our prototype to reach a higher overall throughput given the Dualon flat-top transmission profile compared to the sharp transmission peaks of standard etalons, see [1]. We will then proceed with on sky observations on an existing telescope.

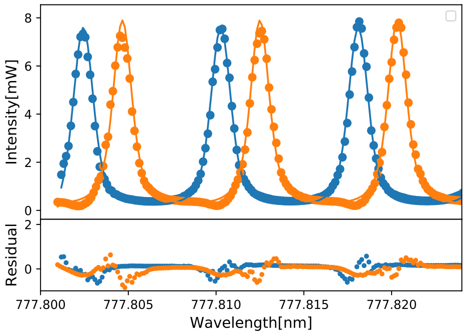

Figure 2: The signal from the first arm (blue) and second arm (orange) of the FPI prototype fed by a single mode fiber. The dots are data points and overplot is a convolved model. Each obtains FWHM 0.00123211 nm and 0.00123221 nm respectively, corresponds to the spectral resolution of R = 632,361.

Acknowledgements

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References

[1] Ben-Ami, S., et al., ApJ, 861, 2, Pp. 79, 2018.

[2] Charbonneau, D., et al., ApJ, 568:377–384, 2002.

[3] López-Morales, M., et al., arXiv e-prints, 2019.

[4] Rodler, F. & López-Morales, M., ApJ, 781, 54, 2014.

[5] Sagan, C., et al., Nature, 365:715–21, 1993.

[6] Seager, S., & Sasselov, D. D., ApJ, 537, 916-921, 2000.

[7] Segura, A., et al., Astrobiology, 5:706–725, 2005.

[8] Snellen, I.A.G. et al., ApJ, 764, 182, 2013.

[9] Szentgyorgyi, A., et al., Proc. SPIE, 9908, 990822, 2016.

[10] Vaughan, J.M., The Adam Hilger Series on Optics and Optoelectronics, Bristol: Hilger, 1989.