Atmospheric Composition Retrieval from Transit Spectra of Terrestrial Exoplanets: A Feasibility Study using Earth Observations

S. Städt[1], F. Schreier[1] and Mareike Godolt[2]

1 - DLR – German Aerospace Center, Remote Sensing Technology Institute, Oberpfaffenhofen, Germany

2 - Center for Astronomy and Astrophysics, University of Technology Berlin, Germany

Only have 1 minute? Then just look at the **bold text**, the figures, the table and the conclusion

Introduction

- around 3500 confirmed exoplanets including super Earths
- demand for atmospheric retrievals is rising
- current space missions & telescopes do not have a high resolution and/or the signal/noise ratio is too bad

Main question: **Which molecules are detectable in the atmosphere and what is their concentration?**

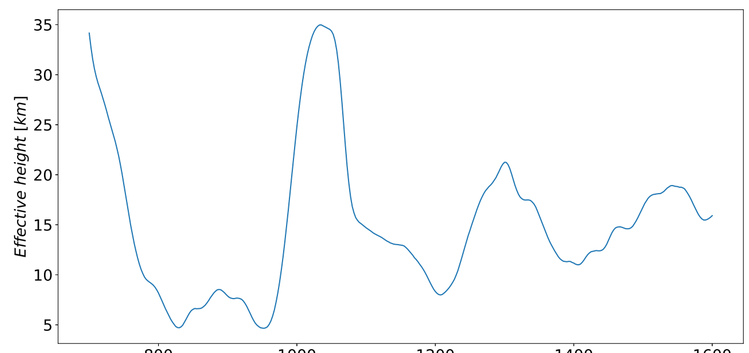

Figure 1: Low resolution, noised global spectrum

Retrieval

- **Forward Model**: Generic Atmospheric Radiation Line-By-Line Infrared Code (GARLIC)[3]
- Combination of MINPACK[2] python version and GARLIC
- **Solve nonlinear inverse problem:** $\min_{\mathbf{x}} \|\mathbf{y} - \mathbf{F}(\mathbf{x})\|^2$ with $\mathbf{y}$ as observed spectrum and $\mathbf{F}(\mathbf{x})$ as simulated spectrum
- **Nonlinear Least-squares** solver: **Levenberg-Marquardt** to find best molecular scaling factors

Data

- Effective height of limb sounding spectra from Earth

$$\textbf{Effective height } h(\nu) = \int_0^\infty (1 - \mathcal{T}(\nu, h_t))\mathrm{d}h_t$$

- High resolution spectra are convoluted and noised to simulate the bad quality of an exoplanet spectrum
- Molecular information from HITRAN database[1]

Results

- The optimized spectrum has roughly the same course as the observed spectrum
- The **more relevant molecules** are included, the **lower is the residual** norm
- High values of the CFCs are retrieved

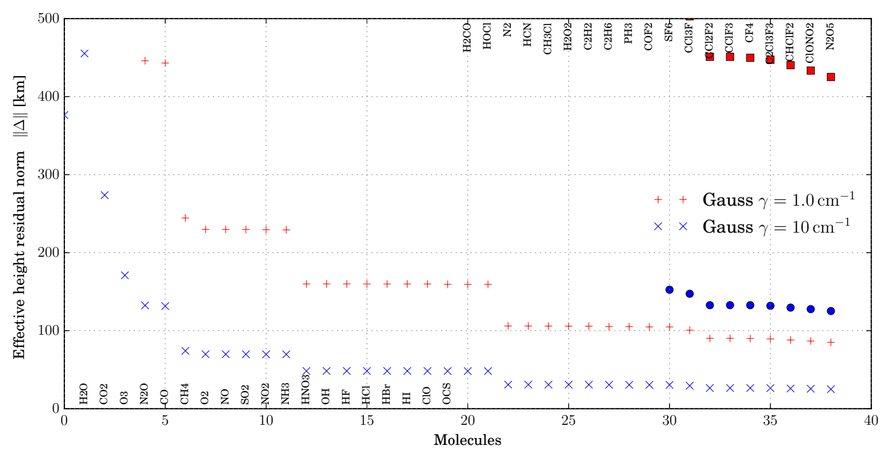

Figure 2: The residual norm in dependency of the number of absorbing molecules with different resolutions.

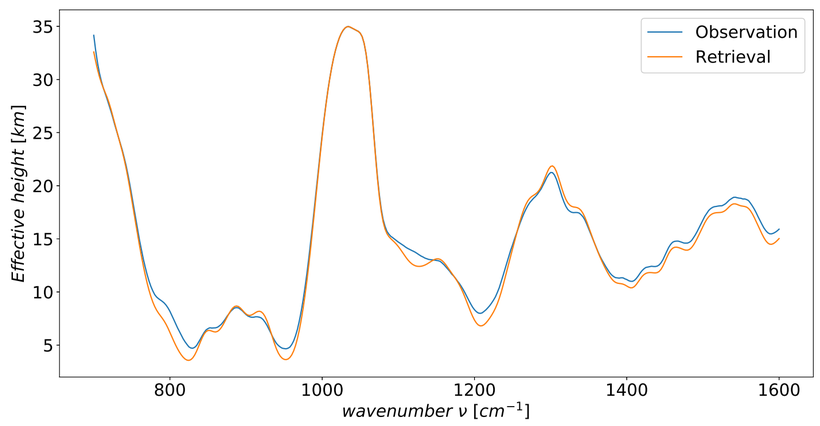

Figure 3: Optimized spectrum with retrieved parameters vs. observed spectrum

Molecule	Value	Error
CO2	1.60802	
CCl2F2	4.12623	0.18
CCl3F	3.01171	0.443
HNO3	1.85666	0.0812
H2O	1.35896	0.0242
CH4	1.93031	0.0456
N2O	2.85799	
O3	1.10118	0.0171
NO2	0.76425	0.0744

Table 1: Retrieved scaling factors

Conclusion

The results show that, the atmospheric retrieval is possible, but

- We do not know which molecules are detectable in the atmosphere of an exoplanet, we only made guesses due to our *a priori* knowledge
- It strongly depends on the S/N ratio and spectral resolution

References

[1] L.S. Rothman et. al. The HITRAN2012 molecular spectroscopic database. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 130(Supplement C):4 – 50, 2013. ISSN 0022-4073. doi: https://doi.org/10.1016/j.jqsrt.2013.07.002. HITRAN2012 special issue.

[2] J. J. Moré, D. C. Sorensen, K. E. Hillstrom, and B. S. Garbow. *The MINPACK Project, in Sources and Development of Mathematical Software*. Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 1984.

[3] F. Schreier et al. GARLIC — a general purpose atmospheric radiative transfer line-by-line infrared-microwave code: Implementation and evaluation. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 137:29 – 50, 2014. doi: http://dx.doi.org/10.1016/j.jqsrt.2013.11.018.

Institut Methodik der Fernerkundung
DLR Oberpfaffenhofen
D-82234 Wessling
Internet: www.dlr.de/eoc