Know thy Neighbor: Solar System Analog Observations for Exoplanet Science

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Summary

Interpretations of high-quality spectroscopic observations relevant to exoplanet atmospheric characterization require vetted tools. Additionally, using new observations to push the bounds of comparative planetology demands relevant comparison cases. Exoplanet analog observations and studies of solar system worlds, then, are a key avenue both for validating the types of models often used in exoplanet remote sensing and for yielding data for comparative planetology studies. This poster provides a review of available solar system exoplanet analog observations alongside a discussion of ongoing attempts to use these data in mission design and to test approaches to atmospheric retrieval.

Why it Matters

Exoplanet analog observations of solar system worlds:

- can **help you validate your retrieval models**. Exoplanet inverse models face the challenging task of making inferences about a wholly unknown planetary environment from (sometimes very) noisy data. Application of these tools to solar system worlds affords developers the opportunity to test retrieval model functionality and parameterizations on real planets where the surface/atmospheric state is well-known.

- will **help you prepare for future missions**. Missions like NASA's Habitable Worlds Observatory (HWO) and ESA's Large InterFerometer for Exoplanets (LIFE) will be able to glimpse exoplanetary systems like our own. Analog observations of solar system worlds can then stand in as planetary target data for these missions.

Figure 1: Example exoplanet analog observations of solar system worlds. Earth from *EPOXI* (top-left; Livengood+ 2011), Earth from *Galileo* (top-right; Strauss+ 2024), Jupiter from *Cassini*/ISS (bottom-left; Mayorga+ 2016), Titan from *Cassini*/VIMS (middle-right), and Jupiter's phases from *Cassini*/ISS (lower-right; Li+ 2018).

Example Application

Robinson and Salvador (2023) used exoplanet analog observations of solar system worlds to explore retrievals relevant to JWST, HWO, and LIFE. Webb-like retrievals on a Titan transit spectrum produced results consistent with *Cassini*/*Huygens*. HWO-like retrievals on UV/visible/NIR observations of Earth from *EPOXI* revealed that spectra at SNR of 10 may not sufficiently constrain the planetary environment. Finally, LIFE-relevant retrievals on an Earth IR emission spectrum showed issues with constraining the atmospheric thermal structure.

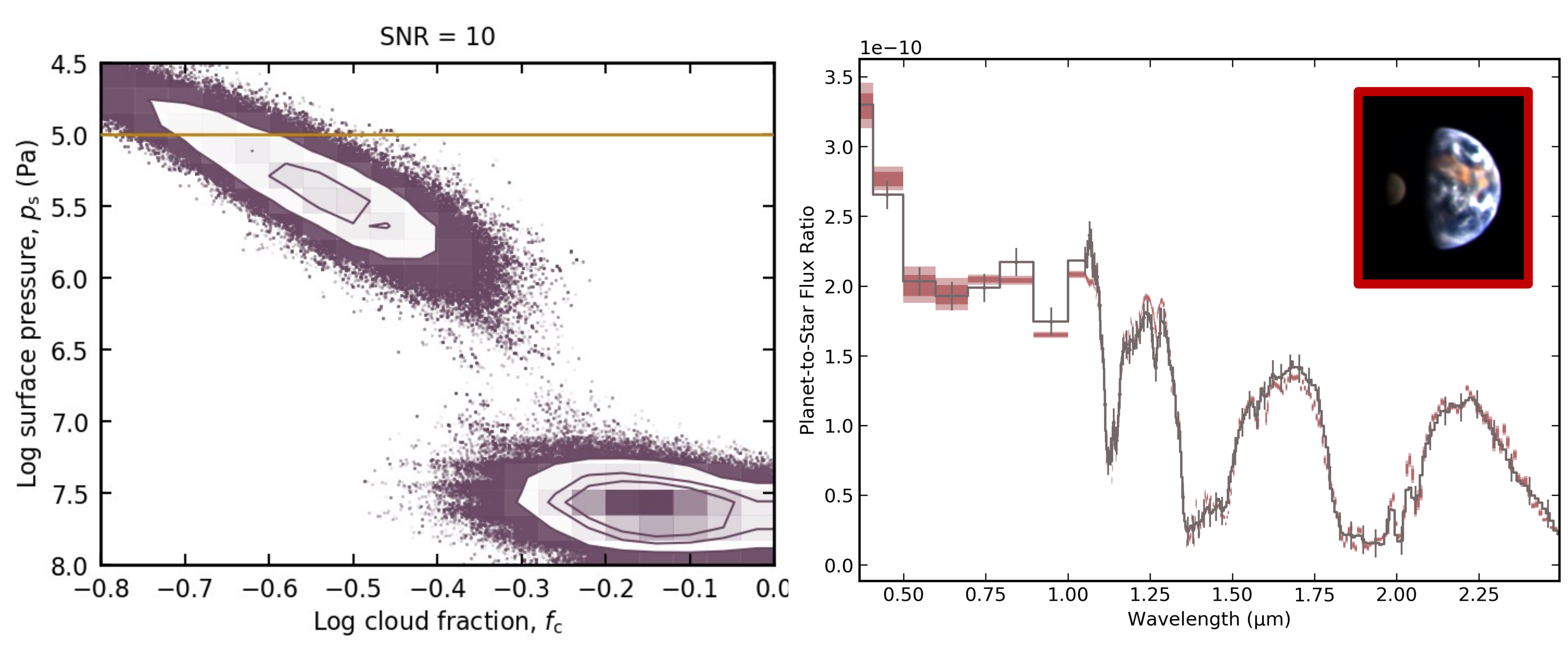

Figure 2: Retrievals (left) on Earth observations (right) reveal that, at low SNR, the inverse model could not distinguish between two atmospheric states: a patchy-clouded world with ~1 bar surface pressure (i.e., true Earth) and a world with an effectively infinite atmosphere below a global cloud deck.

Relevant Observations and Data

Solar system analog data for exoplanet transits can be derived from occultation observations while analogs for direct imaging and secondary eclipse observations demand a whole-disk view. Published, spectrally-resolved datasets are presented in the table below. Notable gaps are apparent, especially for Venus and Mars. The authors welcome information on other relevant datasets!

World	Transit	UV	VIS	NIR	IR
Earth	Macdonald+ (2019)	Robinson+ (2014a)	Livengood+ (2011)	Livengood+ (2011)	Christensen+ (1997)
Jupiter		Li+ (2018)	Li+ (2018)	Mayorga+ (2016)	Li+ (2012)
Saturn	Dalba+ (2015)	Karkoschka (1998)	Karkoschka (1998)		
Titan	Robinson+ (2014b)	García-Muñoz+ (2017)	García-Muñoz+ (2017)		
Uranus/Neptune		Karkoschka (1998)	Karkoschka (1998)		

More Information

Web & Data: www.hablab.net

Email: tdrobin@arizona.edu

Software: www.github.com/hablabx

References

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