Effect of Clouds on Spectral Retrieval

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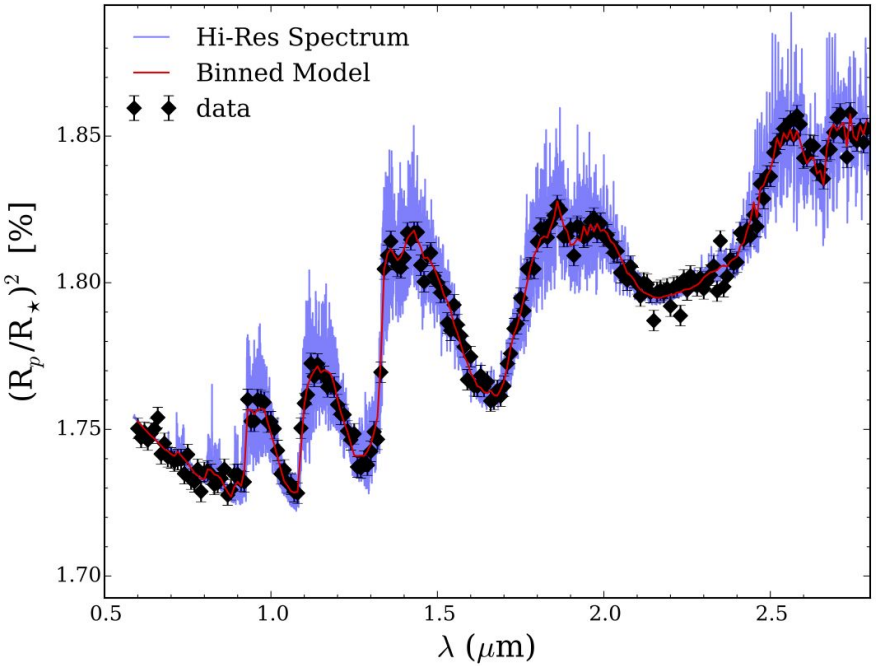
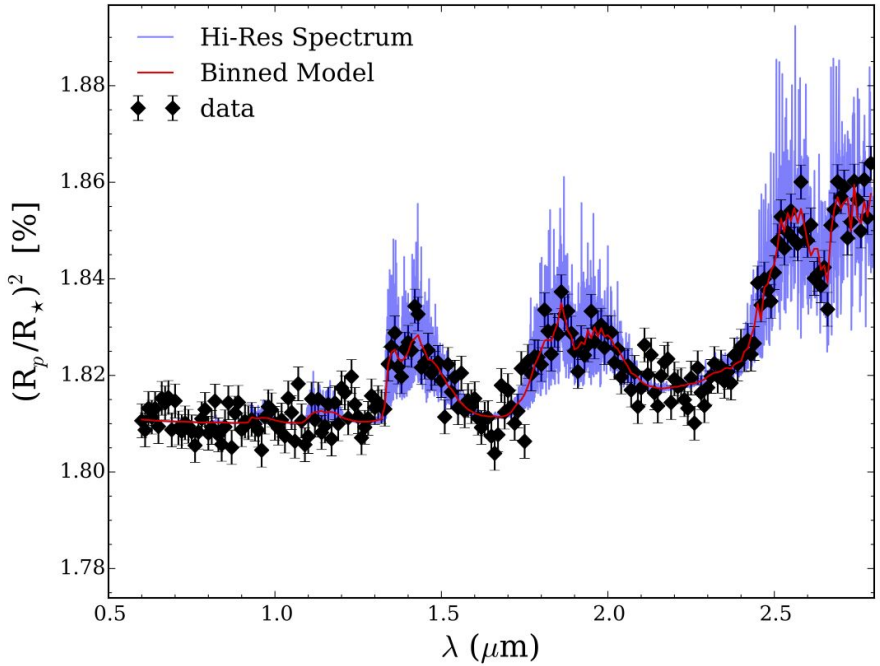
Clear



Cloudy

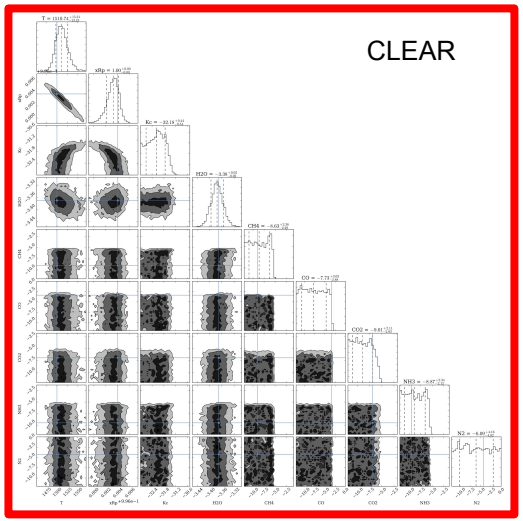


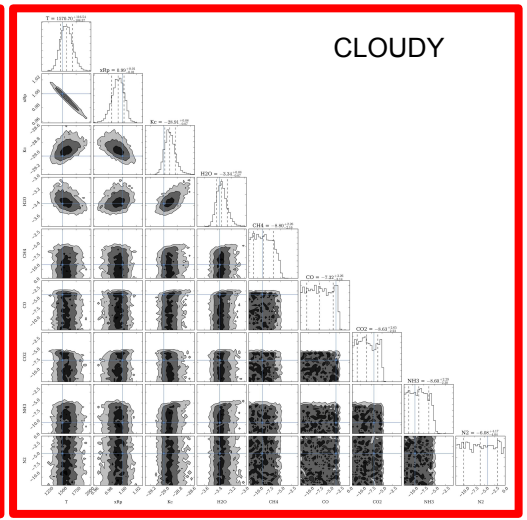
Make sense out of posterior distributions for 3 atmospheric retrievals

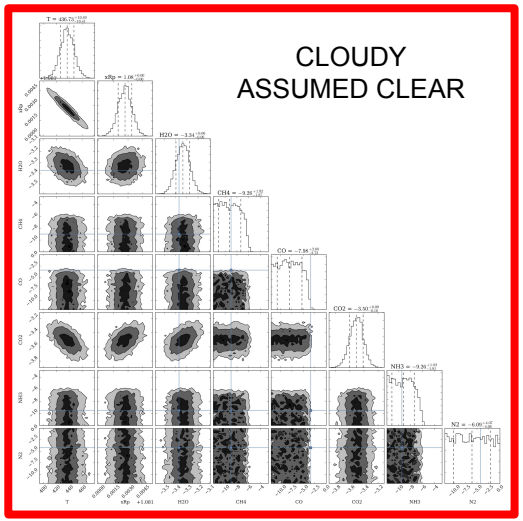
Parameters fit: Temperature, Planet Radius, Cloud Opacity, Molecular Abundances

Things we thought really hard about:

Physical scale of atmosphere above planet surface
How molecular abundances (and corresponding uncertainties) changed
Importance of reasonable model selection



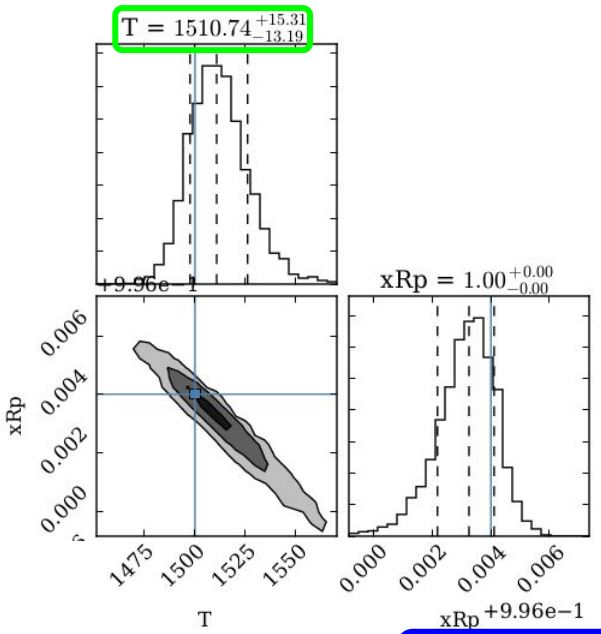




Clouds: Almost Ruining Astronomy Since May 29, 1919

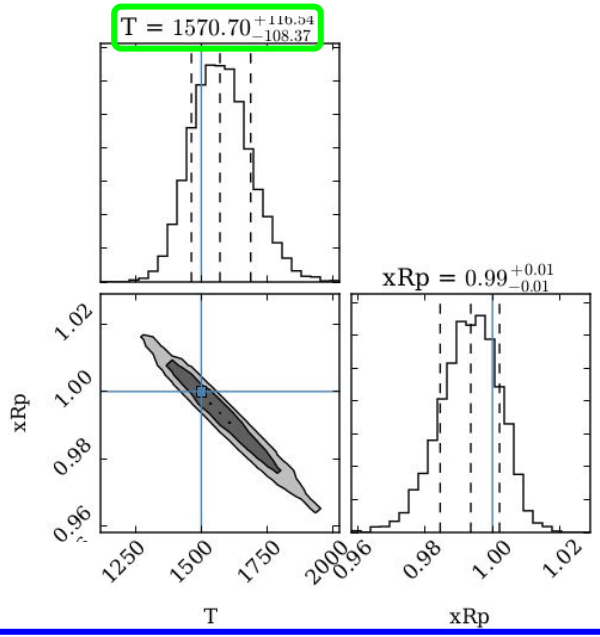
Clear Retrieved with **Clear** Model

Good



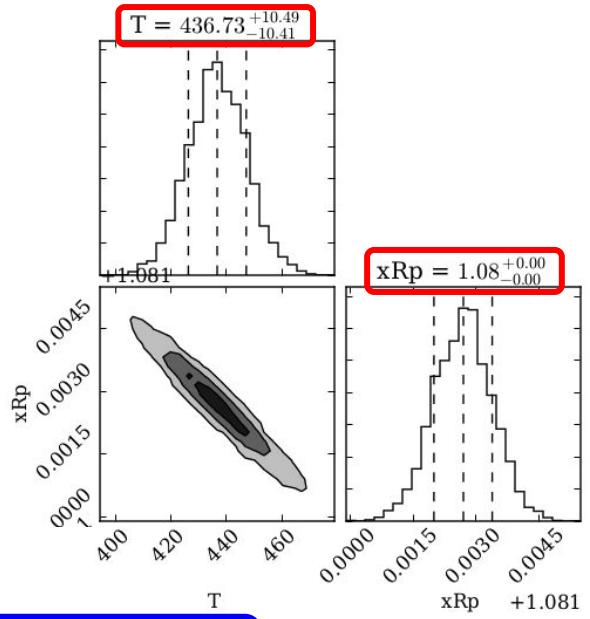
Cloudy Retrieved with **Cloudy** Model

Good



Cloudy Retrieved with **Clear** Model

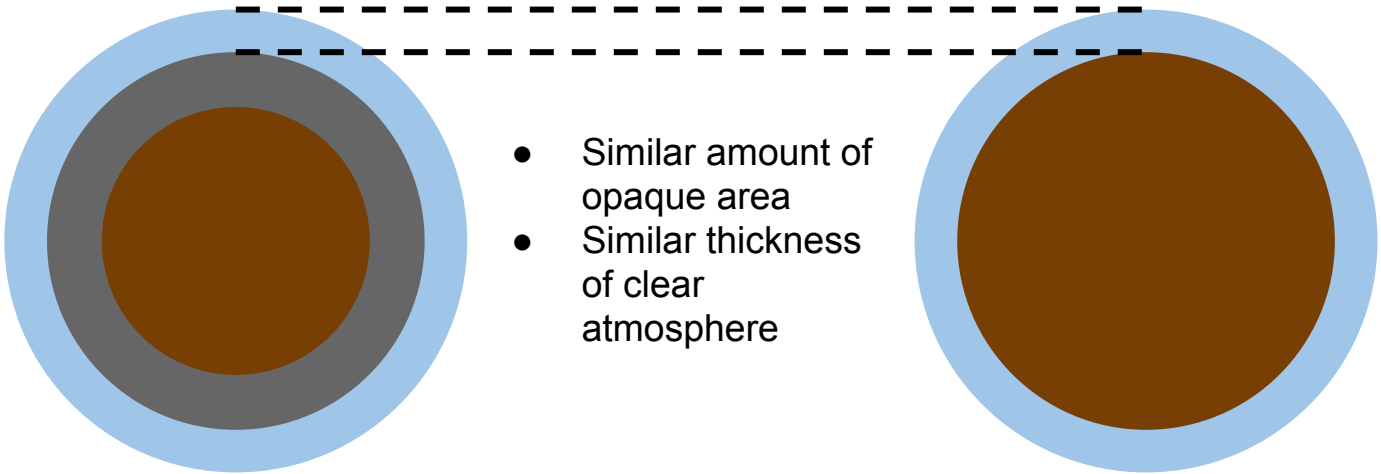
Bad



Take Away: You Can't Ignore Clouds!

A Schematic Explanation

In order to compensate for the model not including clouds, the planet radius increased to adjust the transit depth. The temperature then decreased to get a similar amount of clear atmosphere.



- Similar amount of opaque area
- Similar thickness of clear atmosphere

Small planet with puffy (hot) atmosphere with clouds

Larger planet with thin (cool) atmosphere without clouds

Abundances retrieved

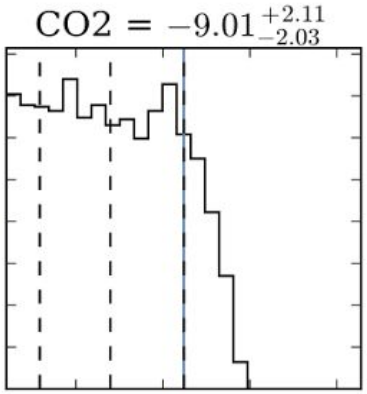
In the cloudy model, the gray absorption of clouds leads to an overall suppression of the spectral features. The SNR of the spectrum is hence lower, the uncertainties on the various abundances increased (especially H20 which is the dominant species in this particular atmosphere)

Curiously, we also noticed when the cloudy model was retrieved without taking the clouds into account, we saw a false detection of CO2. We think the reasons are two-fold:

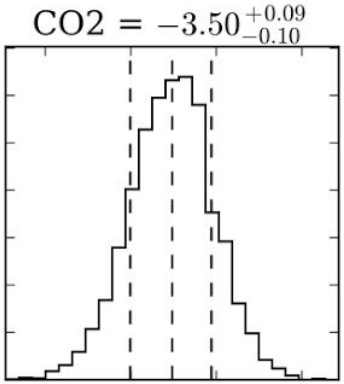
1) increasing CO2 abundance increases the mean molecular weight of the atmosphere and thus decreases the scale height. As a result, the entire spectrum shifts down.

2) Increasing CO2 abundance helps to account for the remaining spectral features.

Clear

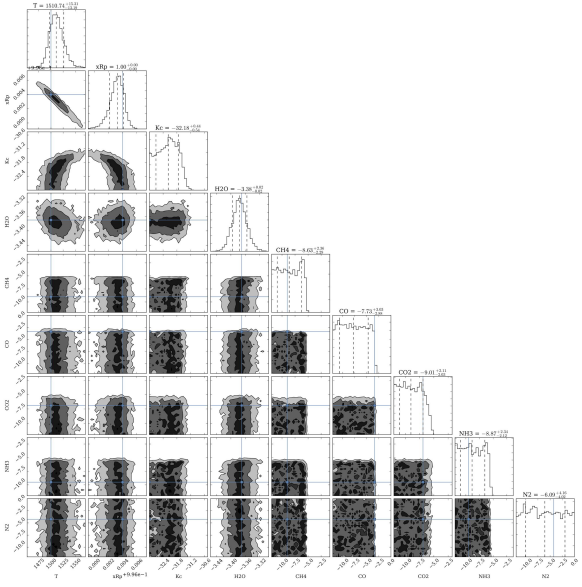


Cloudy retrieved as clear

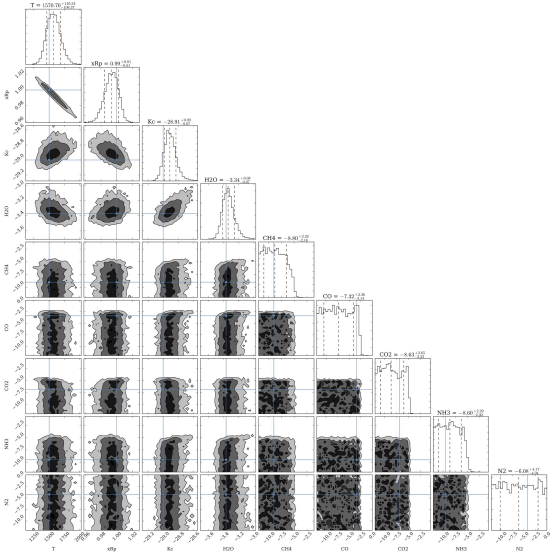


These problems are largely solved when clouds are properly accounted for, the abundances of various molecular species in the cloudy model are now consistent with the clear model. We argue that this success owes to the fact the clouds have not completely suppressed the spectral features. As you will see in next slide, the “cloudy” model is actually not very cloudy, it still preserves many of spectral features. We suspect in the most extreme case, when clouds completely inundate the spectral features, retrieval models will probably not tell us much about the atmosphere.

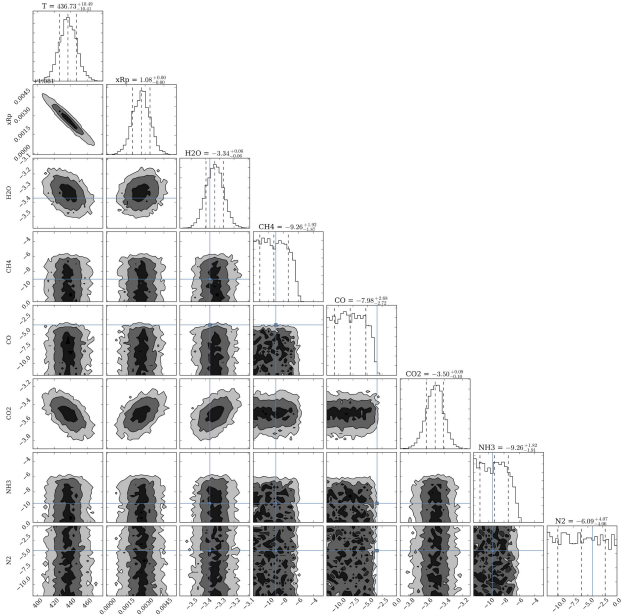
Clear



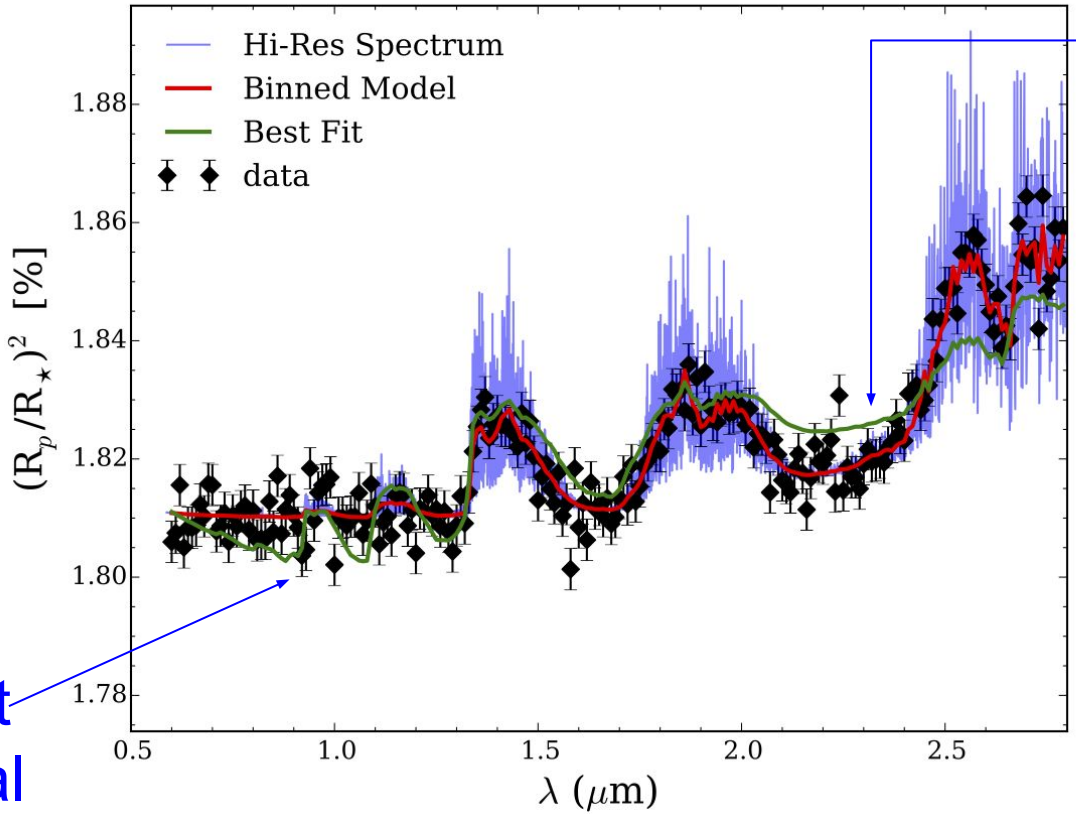
Cloudy



Cloudy retrieved as clear



Cloudy Atmosphere fit with Clear Model



Clearly does not match

Fit has spectral features that are NOT real

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Yay!

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But incorrect assumptions in the underlying model can severely affect the conclusions we draw

so include all relevant effects in your model

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A visual check of the spectra can reveal an underlying issue that may not be immediately clear from the MCMC outputs

...so go back and look at your spectra

(and look at chi-squared value)

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Understanding the degeneracies is important to the correct interpretation of data

so spend enough time understanding the model, and how it affects retrieved parameters


Clouds are important!