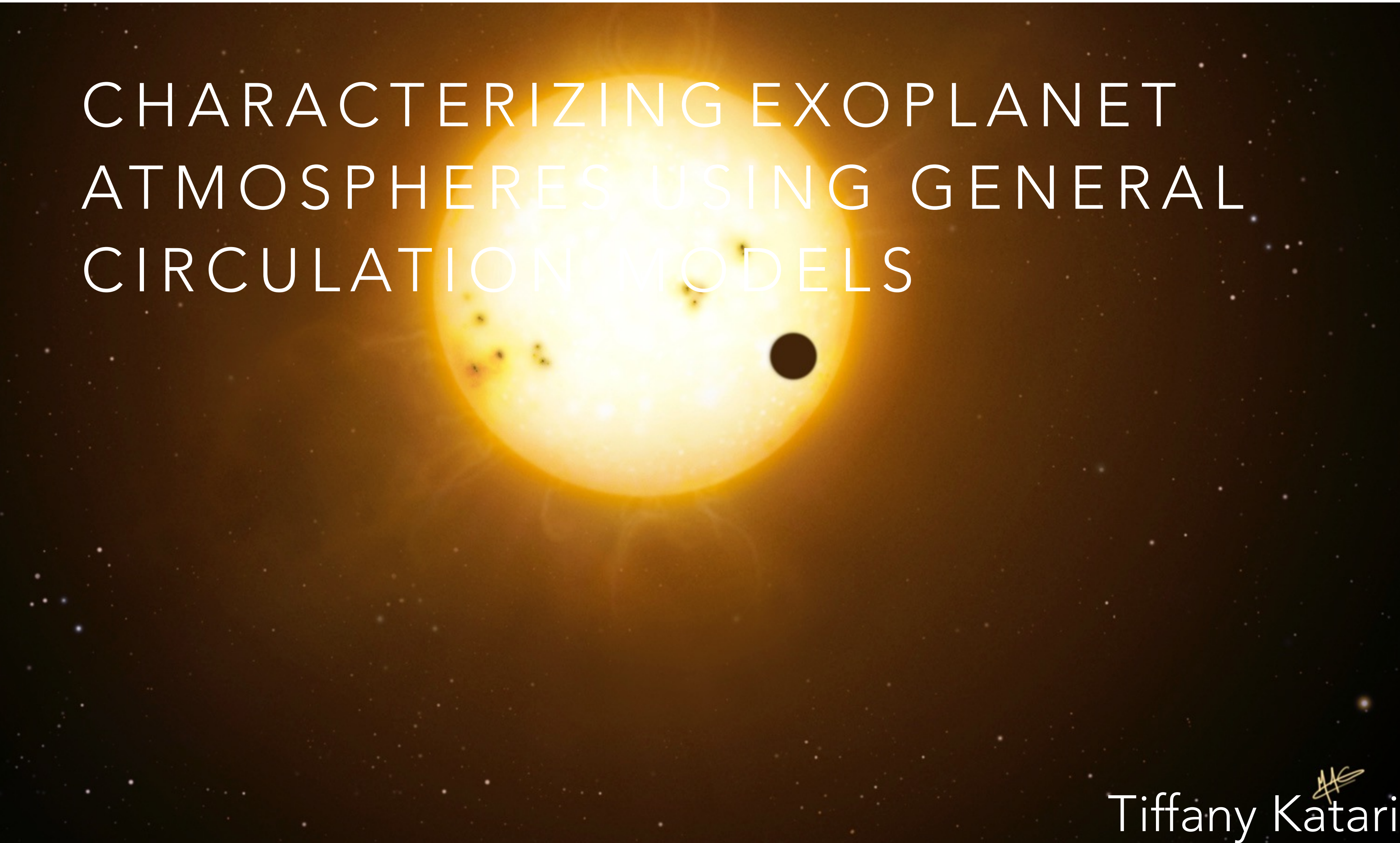
CHARACTERIZING EXOPLANET ATMOSPHERES USING GENERAL CIRCULATION MODELS



Tiffany Kataria

3 July, 2015

With thanks to collaborators David Sing, Adam Showman, Hannah Wakeford, Thomas Evans, Nikolay Nikolov, Jonathan Fortney, Mark Marley, Kevin Stevenson, Nikole Lewis

INTRODUCTION

- Exoplanet circulation modelling
  - Allows us to probe dynamical regimes beyond our own solar system, which expands our overall knowledge of atmospheric dynamics
  - Provides insights to three-dimensional structure
    - Temperature, heating/cooling rates, composition, clouds, chemistry
  - Complements 1-D models in interpreting observations of exoplanet atmospheres: transmission/emission spectra, phase curves, eclipse maps
- Now that we have a (relatively) large observational dataset for a range of planets over a large wavelength range, we can identify trends in atmospheric properties and conduct detailed comparative studies

SAMPLE STUDIES

WASP-43b, an ultra-short period hot Jupiter

Dataset: Spectrophotometric phase curves with HST/WFC3

Objectives: Place constraints on atmospheric metallicity

Large HST program, 10 hot Jupiters observed in transmission

Dataset: Transmission spectra of 10 HJs with STIS and WFC3

Objectives: Understand role of clouds on target sample

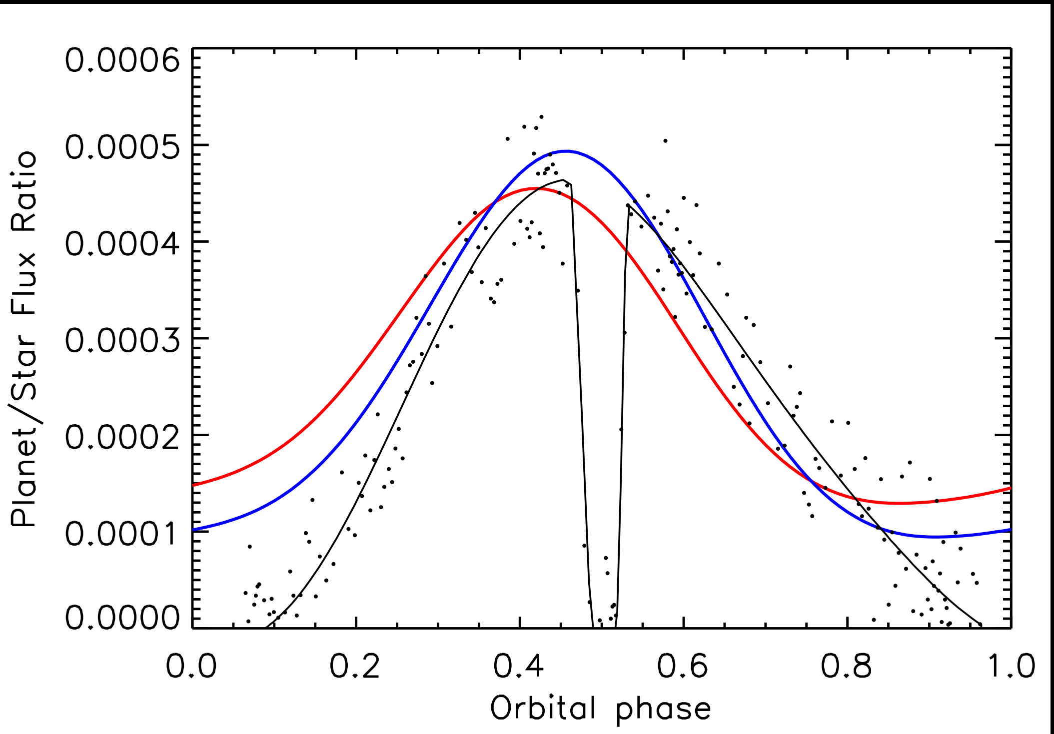
55 Cnc e, an ultra-short period super Earth

Dataset: Spitzer transit/eclipse measurements from 2011-2013

Objectives: Constrain composition and atmospheric variability

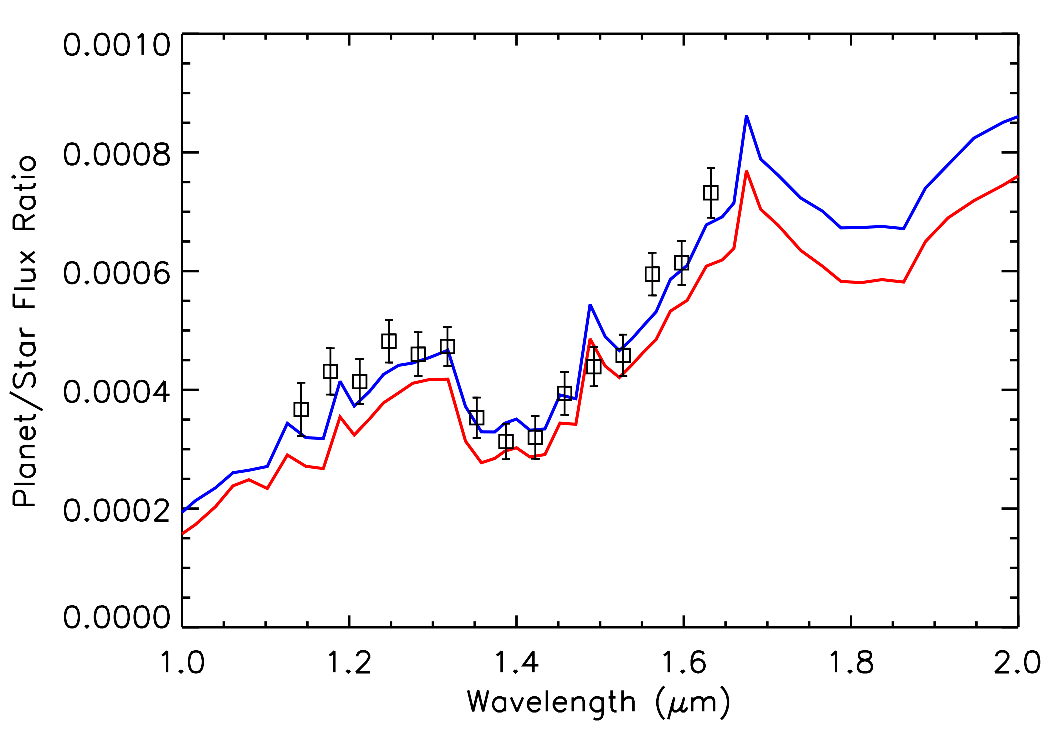
COMPARING GCMS TO SPECTROPHOTOMETRIC DATA: WFC3 OBSERVATIONS OF WASP-43B

Kataria et al. 2015



WHITE LIGHT PHASE CURVE

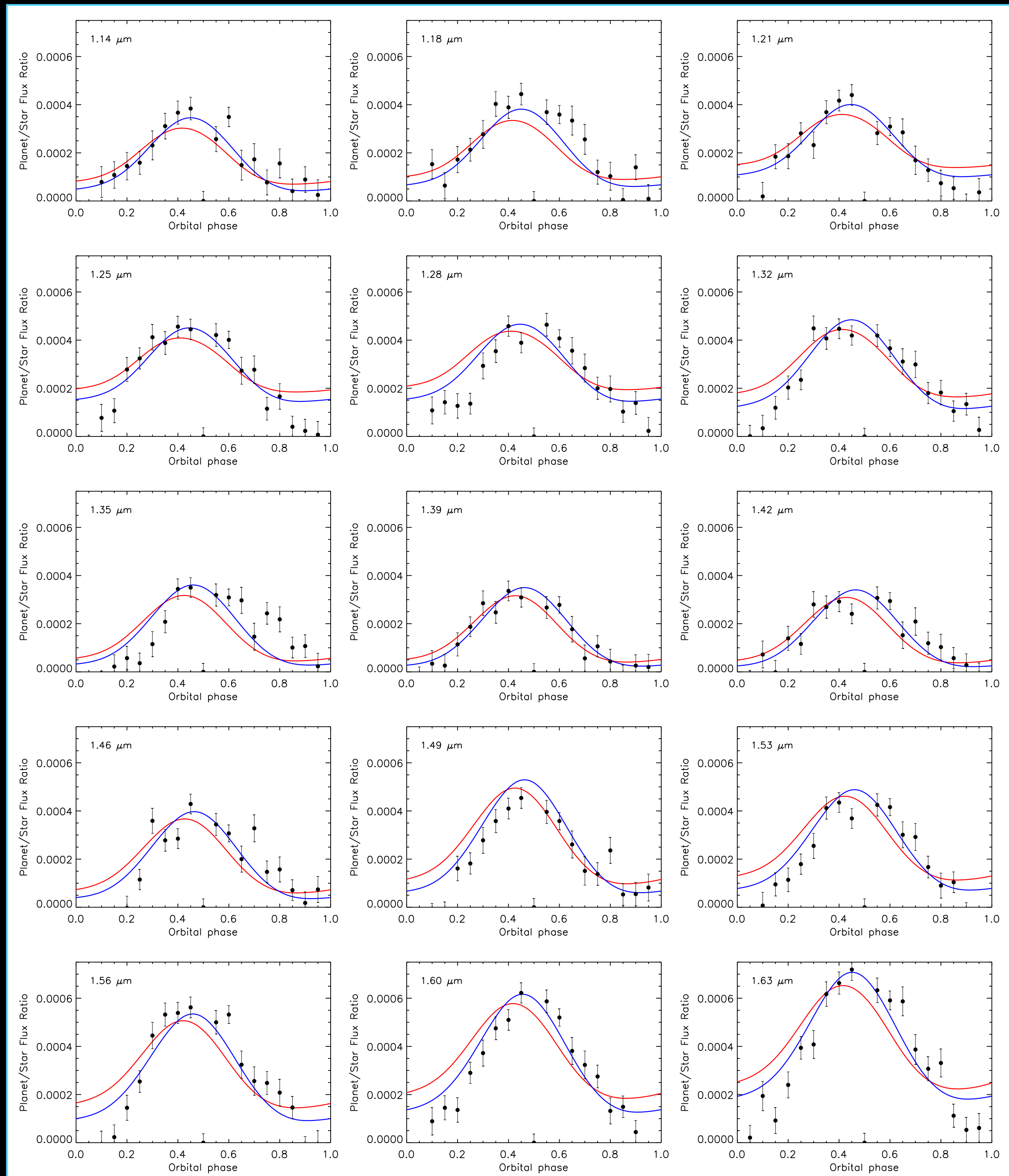
DAYSIDE EMISSION SPECTRUM



COMPARISON TO HST WFC3 OBSERVATIONS

SPECTROPHOTOMETRIC PHASE CURVES

Red: 1x solar model
Blue: 5x solar model

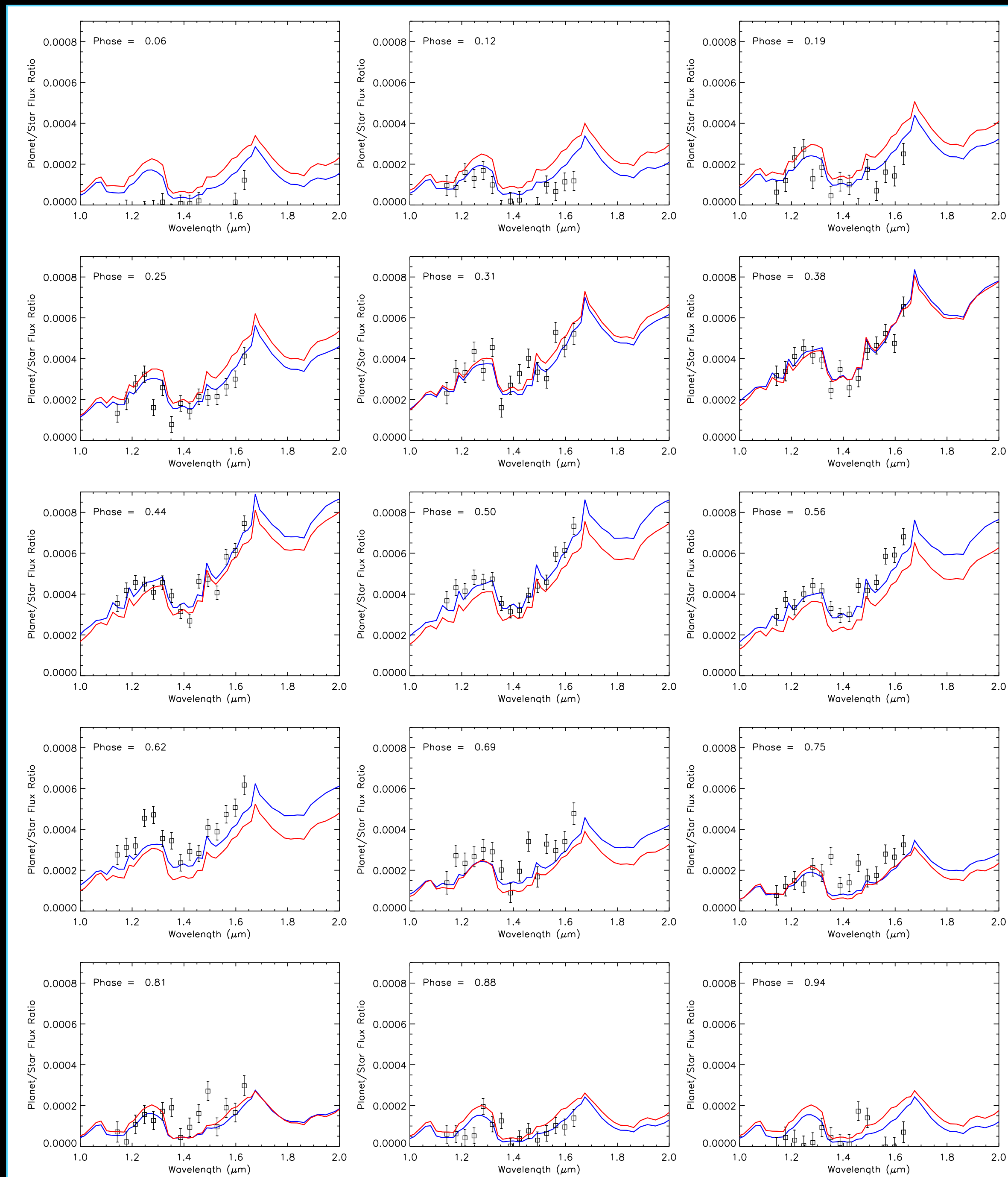


Kataria et al. (2015)

COMPARISON TO HST WFC3 OBSERVATIONS

EMISSION SPECTRA

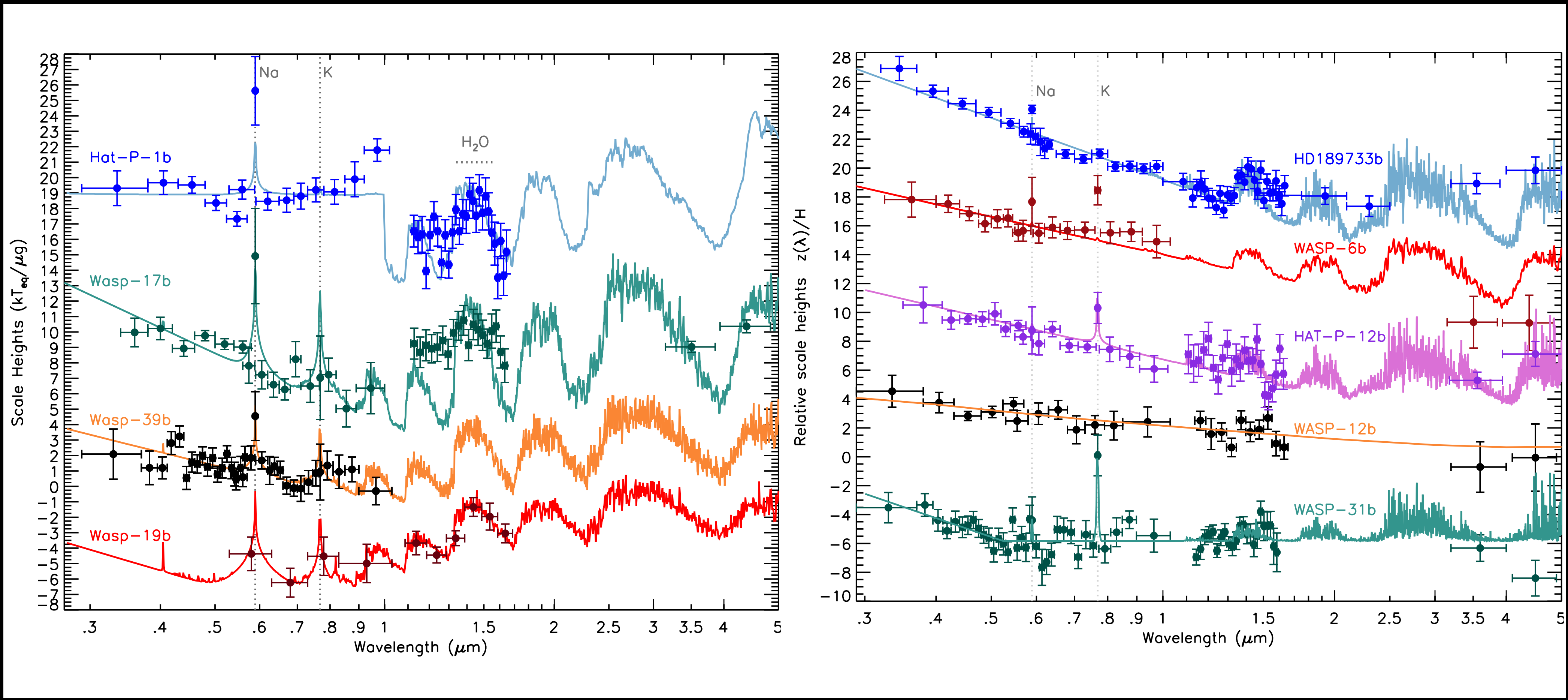
Red: 1x solar model
Blue: 5x solar model



Kataria et al. (2015)

HST LARGE PROGRAM STUDY

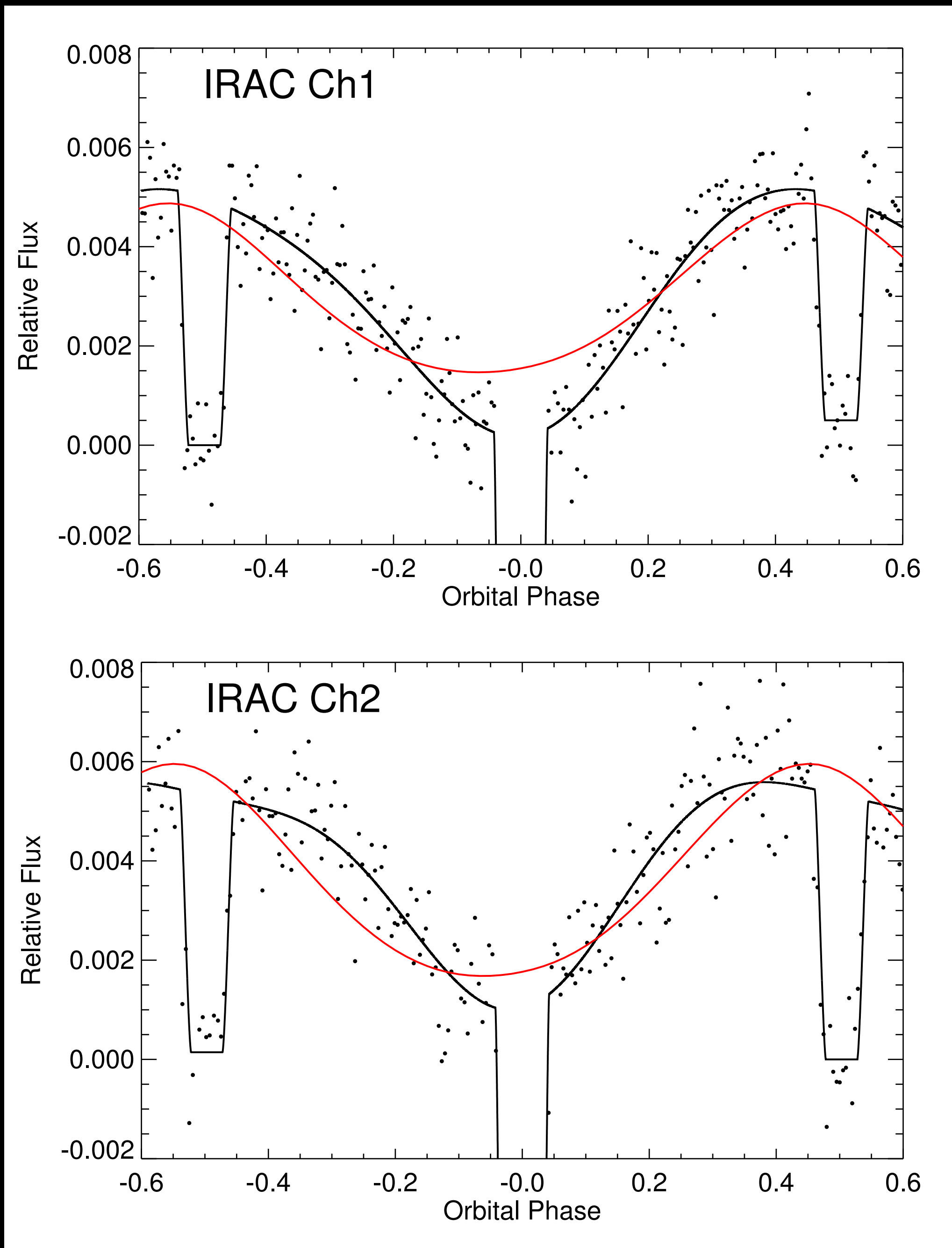
Cloudy versus cloud-free planets

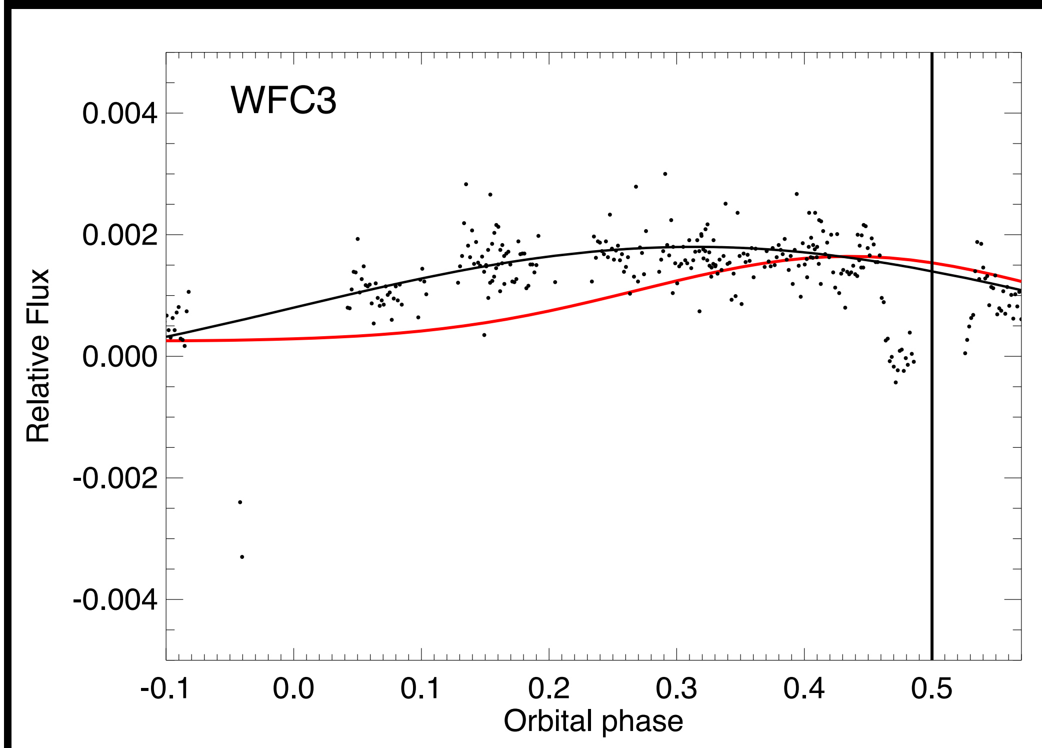


Huitson et al. 2013; Wakeford et al. 2013; Sing et al. 2013, 2015;
Nikolov et al. 2014, 2015; Ballester et al. in prep

WASP-19b

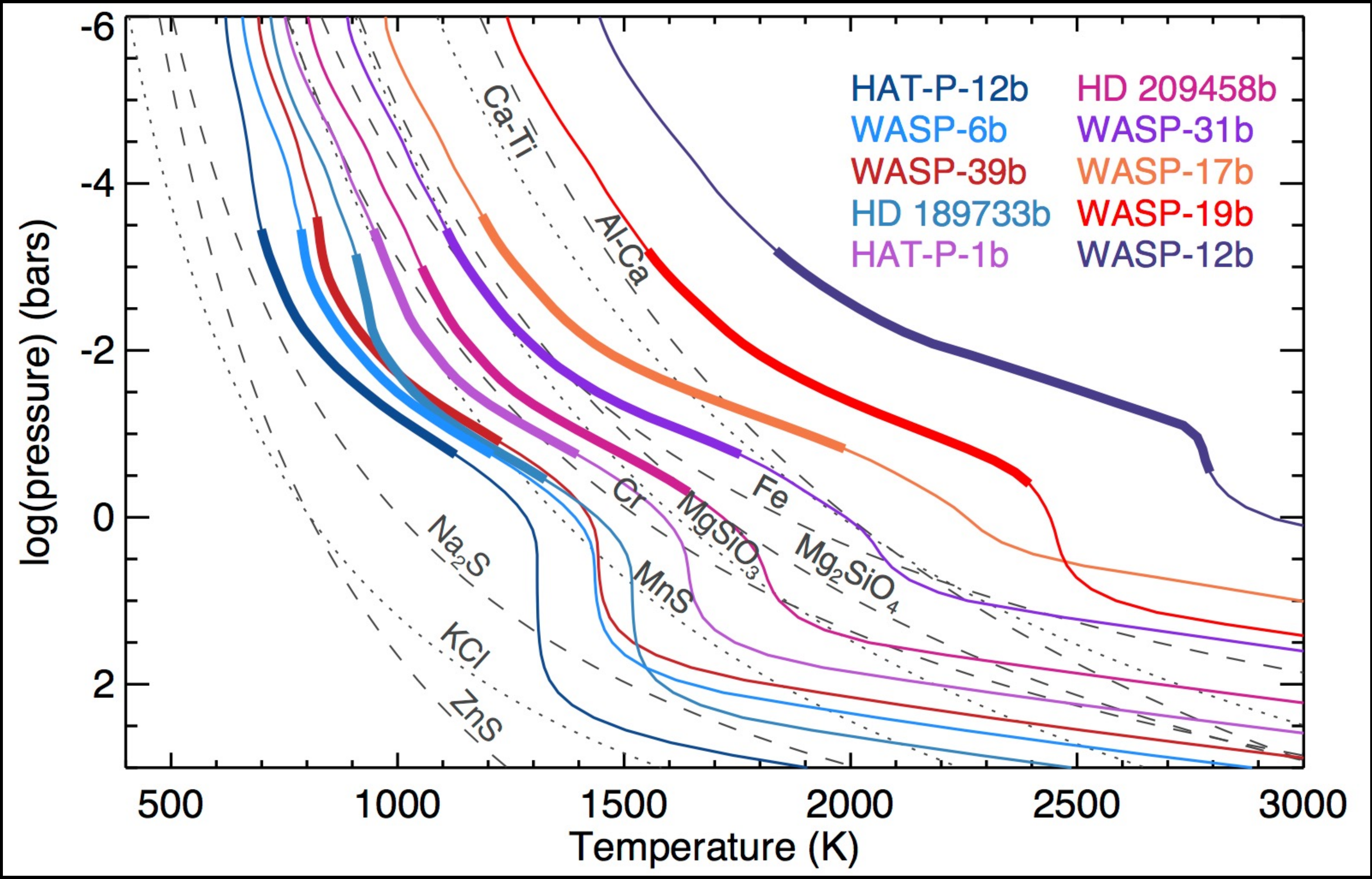
Ultra-short period (~19 hr) planet with a wide array of observational constraints



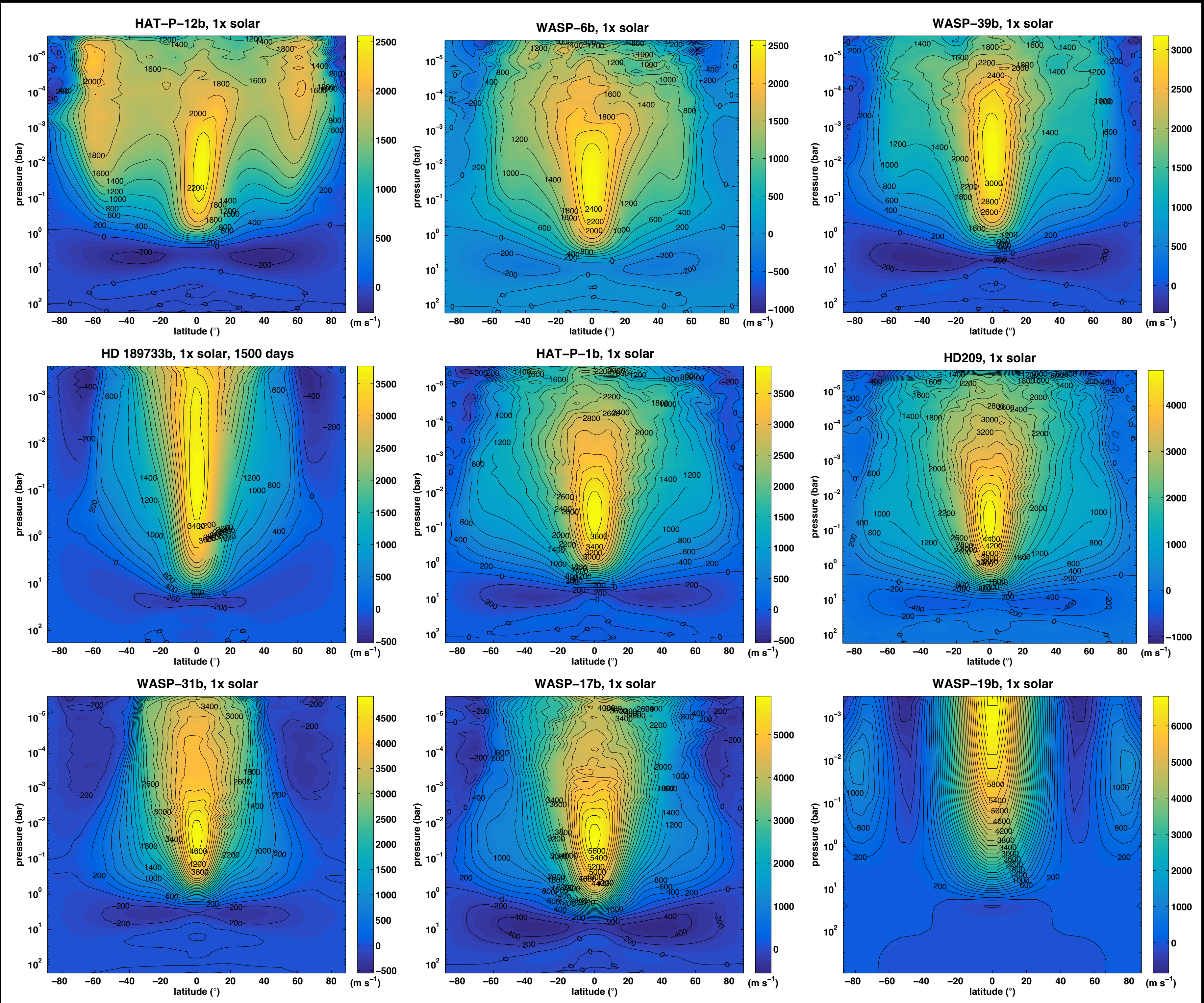


Preliminary reductions by N. K. Lewis and C. M. Huitson

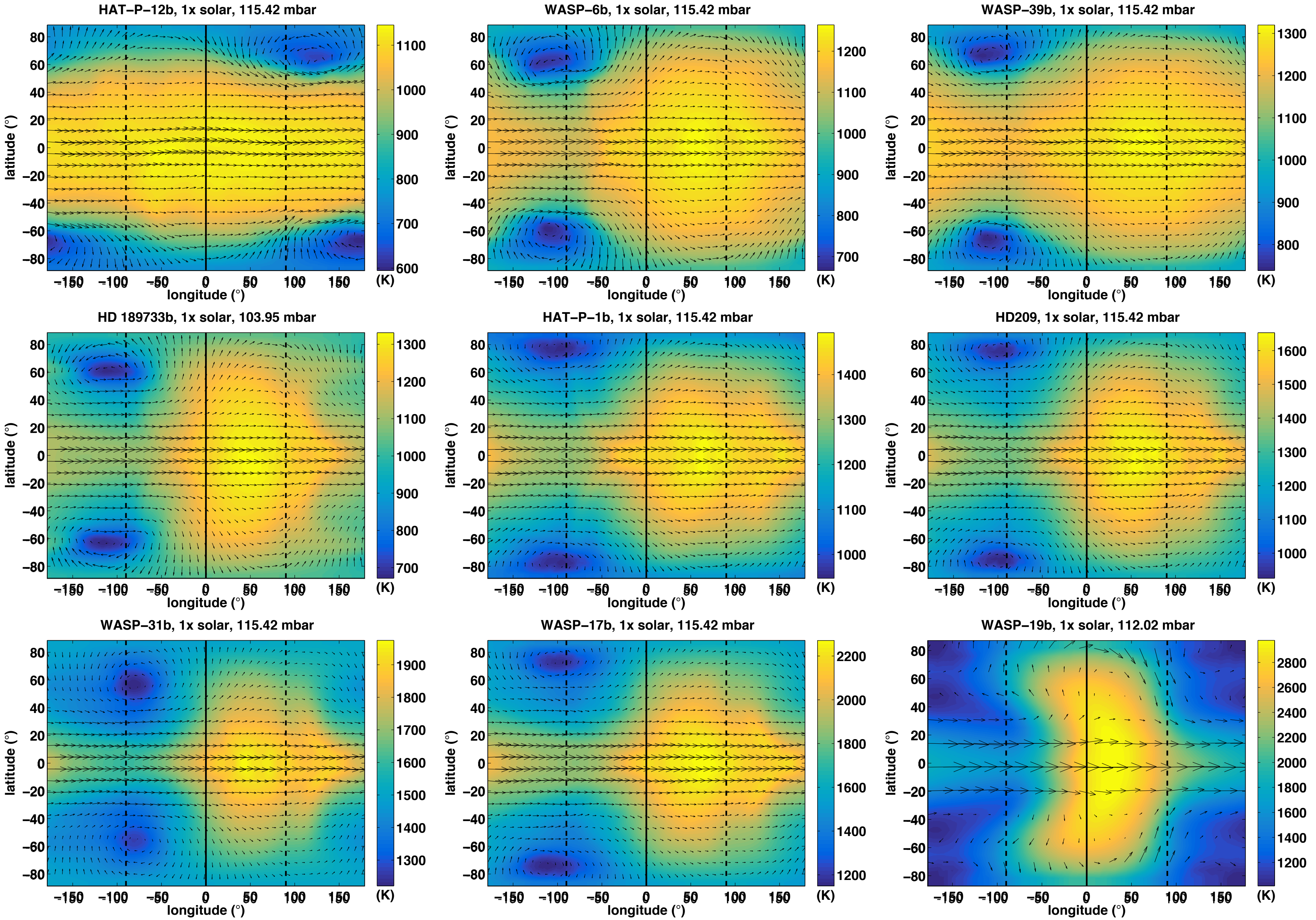
DISENTANGLING CLOUDS



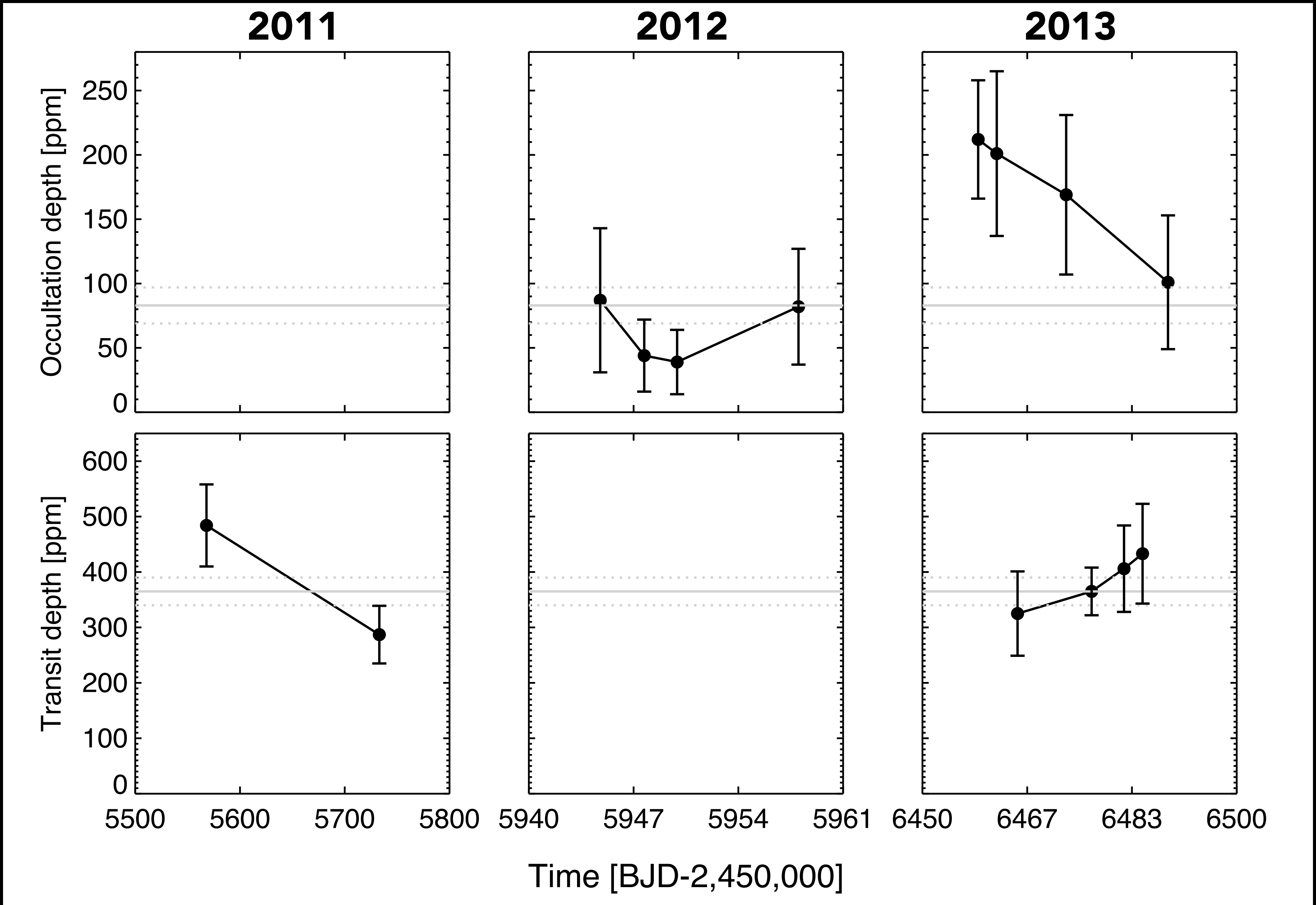
1D radiative equilibrium PT profiles from Jonathan Fortney



HAT−P−12b, 1x solar
WASP−6b, 1x solar
WASP−39b, 1x solar
HD 189733b, 1x solar, 1500 days
HAT−P−1b, 1x solar
HD209, 1x solar
WASP−31b, 1x solar
WASP−17b, 1x solar
WASP−19b, 1x solar
pressure (bar)
latitude (°)
(m s−1)

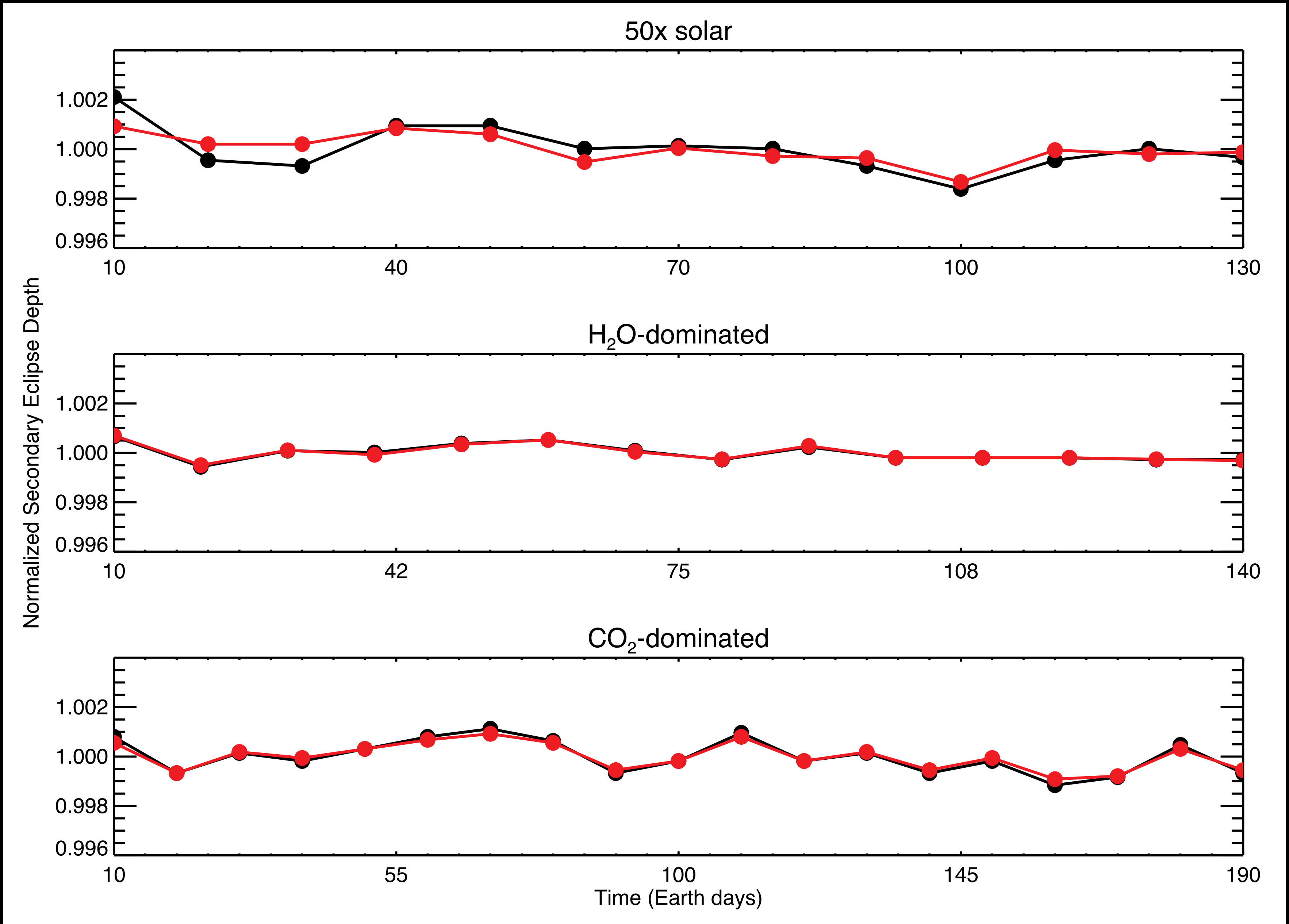

HAT−P−12b, 1x solar, 115.42 mbar
WASP−6b, 1x solar, 115.42 mbar
WASP−39b, 1x solar, 115.42 mbar
HD 189733b, 1x solar, 103.95 mbar
HAT−P−1b, 1x solar, 115.42 mbar
HD209, 1x solar, 115.42 mbar
WASP−31b, 1x solar, 115.42 mbar
WASP−17b, 1x solar, 115.42 mbar
WASP−19b, 1x solar, 112.02 mbar
latitude (°)
longitude (°)
(K)

VARIABILITY ON 55 Cnc e?



Demory et al. 2015

TEMPORAL VARIABILITY



CONCLUSIONS AND FUTURE WORK

- Three-dimensional circulation models can be used to lend insights on a variety of observational datasets, and help answer fundamental questions about their atmospheric properties
- GCM-derived models can provide constraints, but they're not perfect
  - For example, model phase curves generally over-predict nightside flux
  - Enhancement of C/O ratio, disequilibrium chemistry, and/or clouds can be invoked to explain discrepancy, but detailed models are needed to explore these effects
- Need GCMs that encapsulate more complex physics
  - However, with great complexity comes great responsibility
  - Idealized models help identify fundamental dynamical mechanisms