Nick Cowan
(Northwestern)

Potential for Characterization of Transiting Planets with JWST

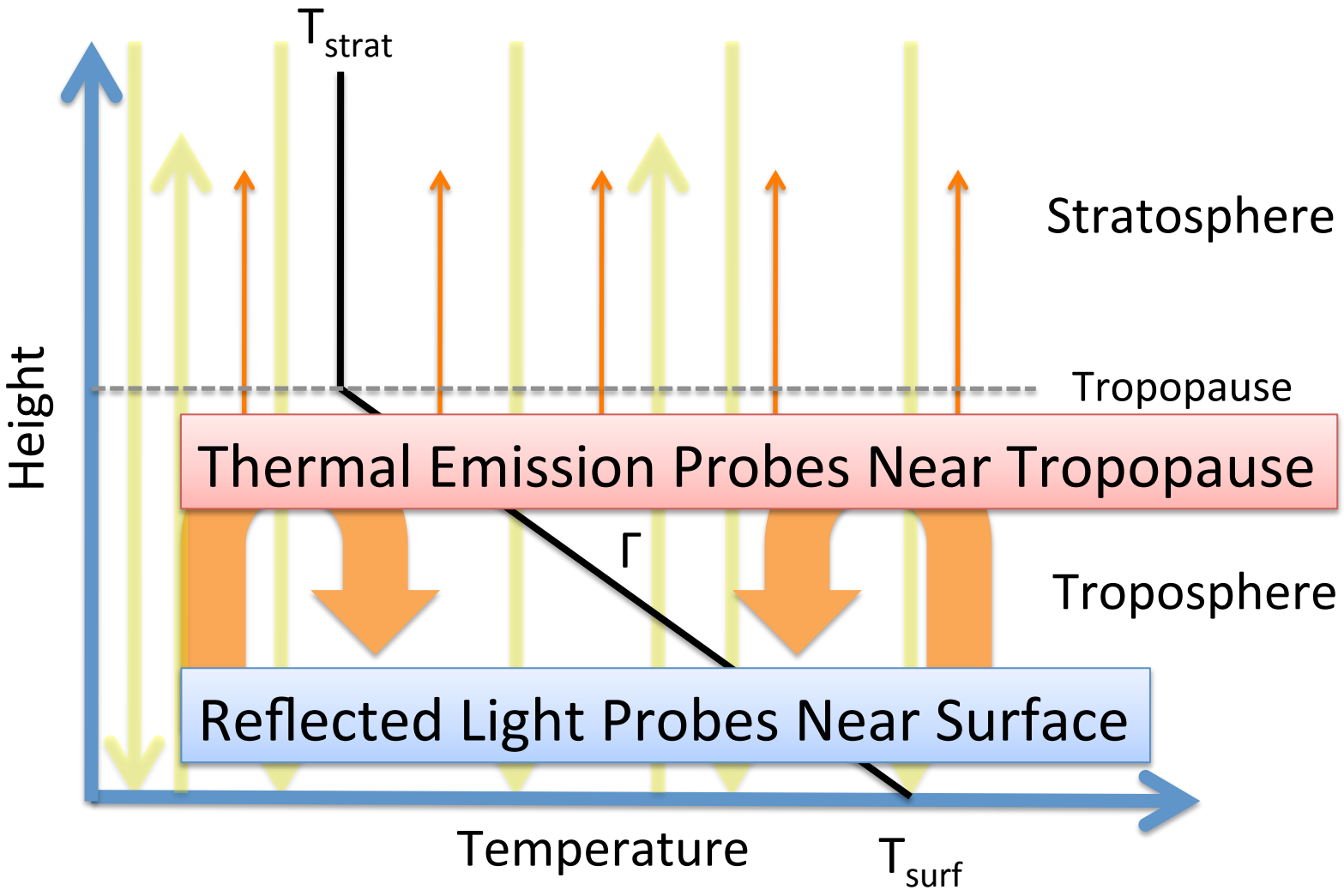
Study Analysis Group 10 (SAG-X)

1. What is the full diversity of planet properties needed to characterize and understand the climate of short-period exoplanets?
2. Which measurement suites and how much observing time are needed to characterize the climate of transiting planets?
3. **Will JWST be able to characterize the atmospheres of transiting terrestrial planets?**
4. **Which critical measurements will be too expensive or inaccessible to JWST**, and can these be obtained with planned observatories?

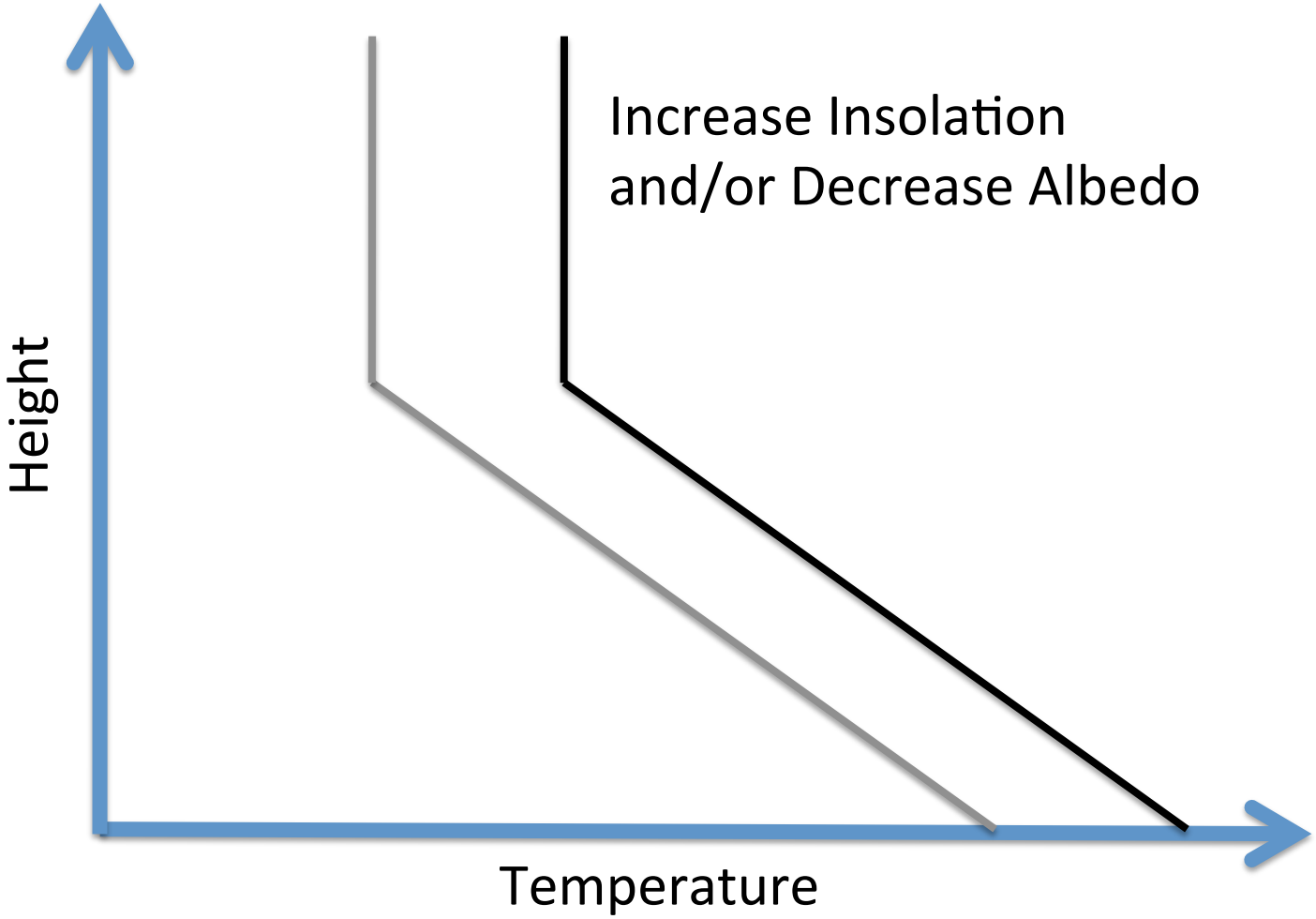
SAG-X Participants (so far)

Daniel Angerhausen (RPI), Natasha Batalha (Penn State), Adrian Belu (Bordeaux), Knicole Colon (Lehigh), Bill Danchi (Goddard), Pieter Deroo (JPL), Jonathan Fortney (UCSC), Scott Gaudi (Ohio State), Tom Greene (Ames), Matt Greenhouse (Goddard), Joe Harrington (UCF), Lisa Kaltenegger (MPIA), Nikole Lewis (MIT), Chuck Lillie (Lillie Consulting), Mercedes Lopez-Morales (CfA), Avi Mandell (Goddard), Emily Rauscher (Princeton), Aki Roberge (Goddard), Franck Selsis (Bordeaux), Kevin Stevenson (Chicago), Mark Swain (JPL)

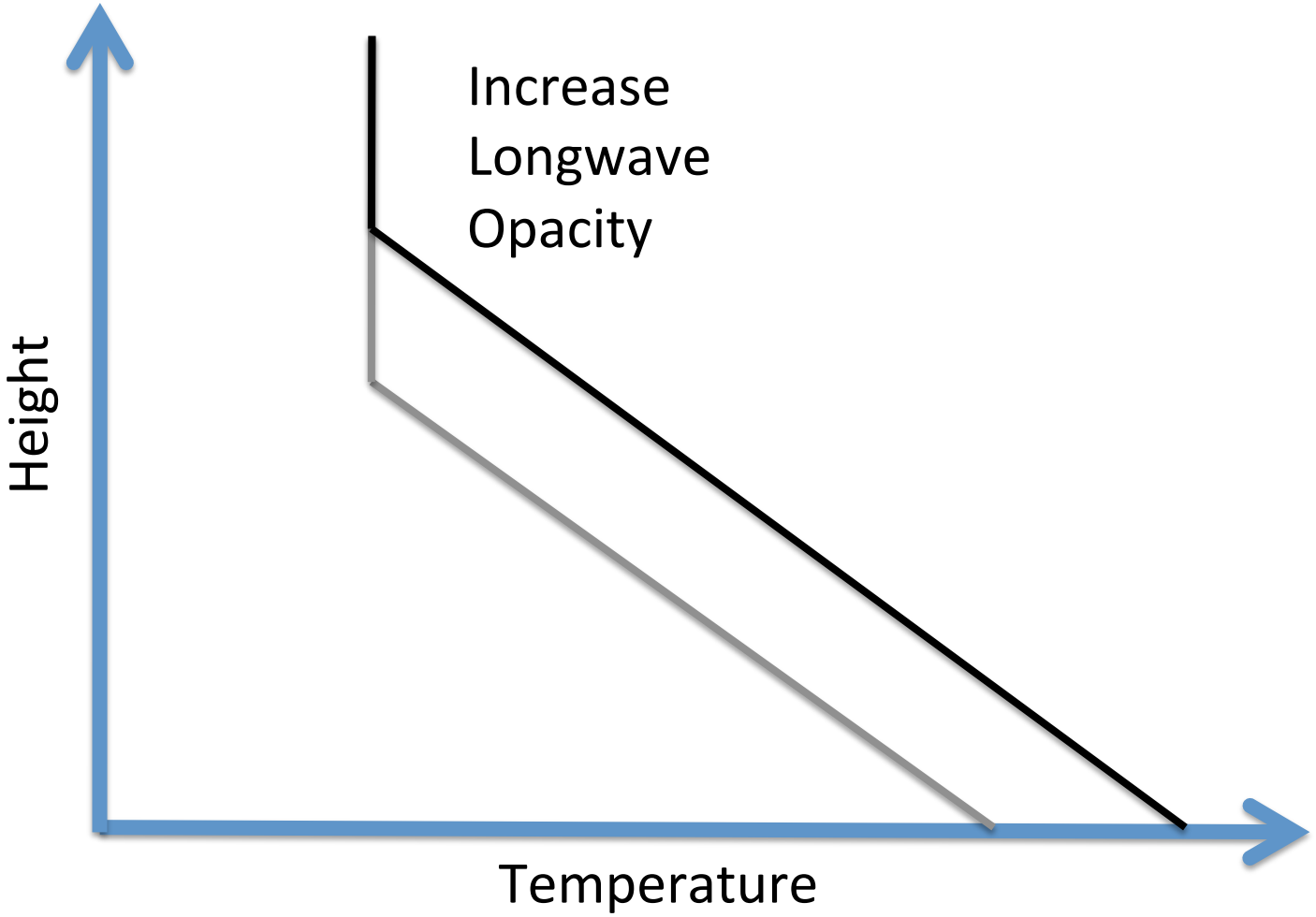
1D Climate Cartoon



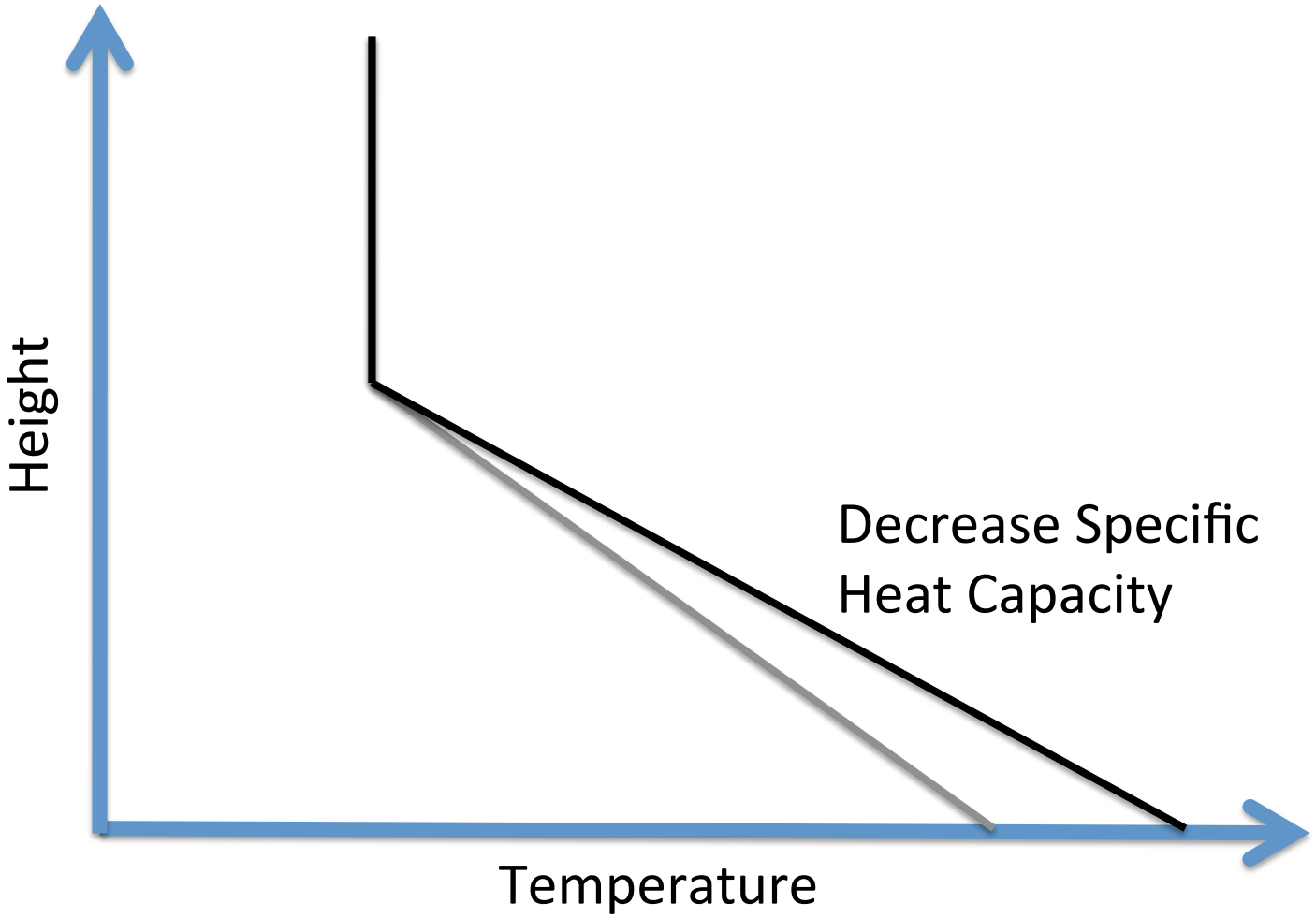
1D Climate Cartoon



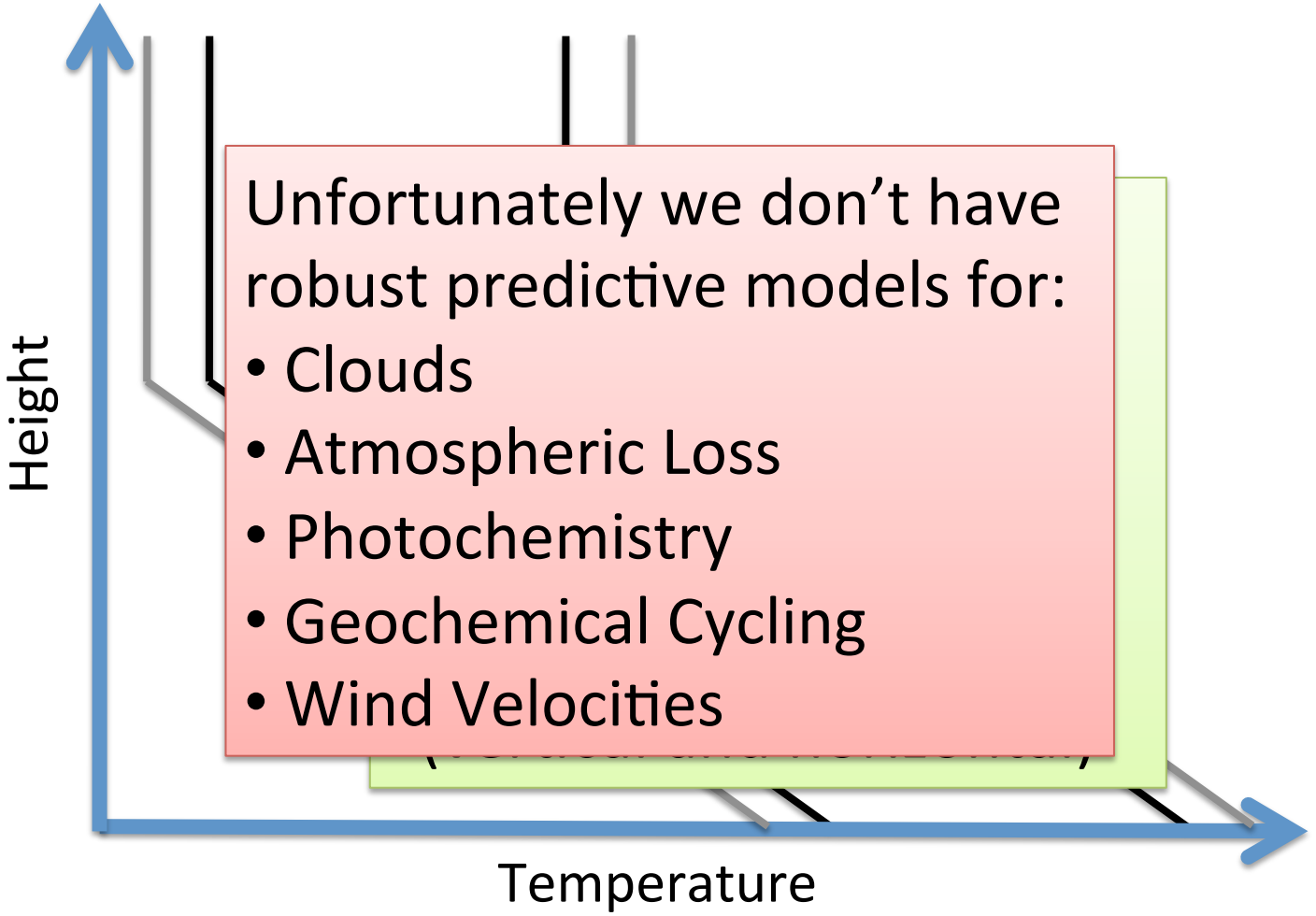
1D Climate Cartoon



1D Climate Cartoon



2D Climate Cartoon
(eg: height + latitude)



Predicting vs Measuring Planetary Climate

Model Inputs

- Insolation
- Eccentricity
- Obliquity
- Surface Albedo
- Greenhouse Gases
- Specific Heat Capacity
- Surface Gravity
- Surface Pressure
- Thermal Inertia

Model Outputs

- Emitting Temperature
- Temperature Gradients
- Diurnal Response
- Seasonal Response
- Cloudiness
- Surface Temperature
- Precipitation

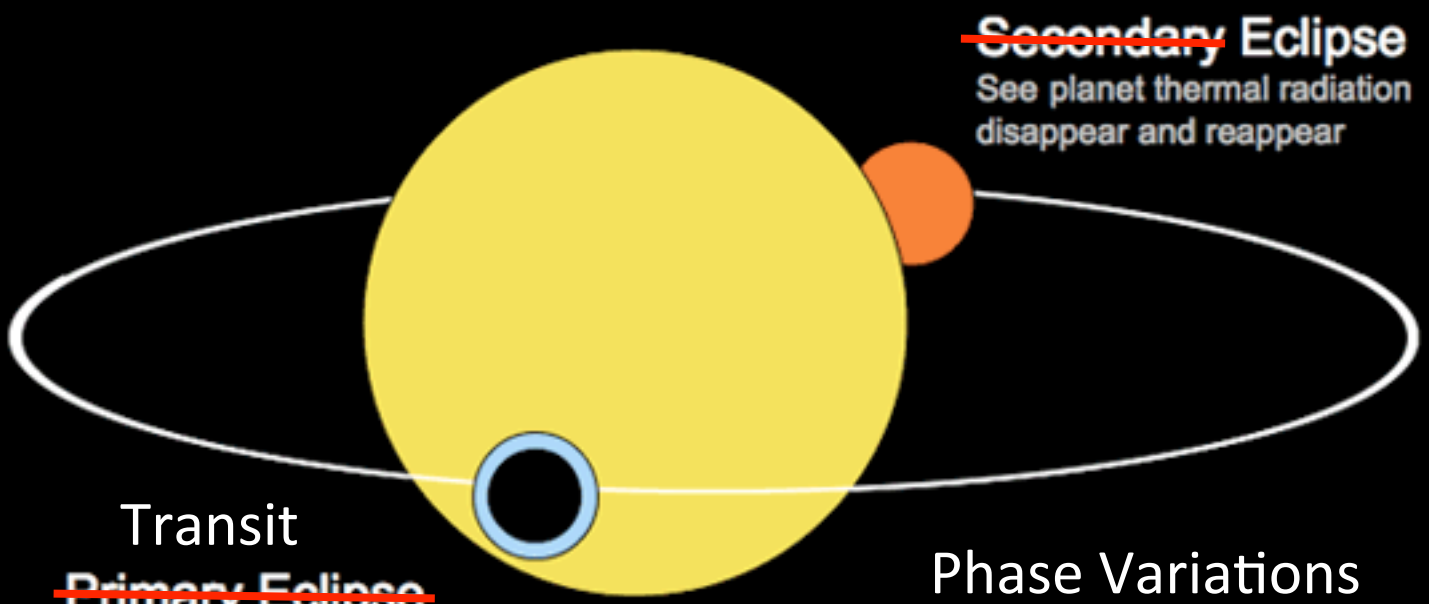
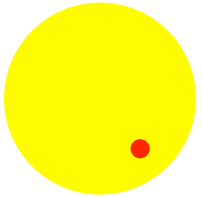


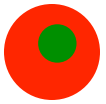
Figure by S. Seager

Archetypal Short-Period Planets

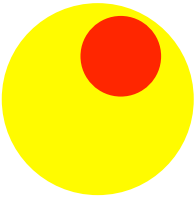
Hot Earth (CoRoT-7b, Kepler 10b, α Cen Bb)



Temperate Super-Earth (HD 85512 b, GJ 163 c)

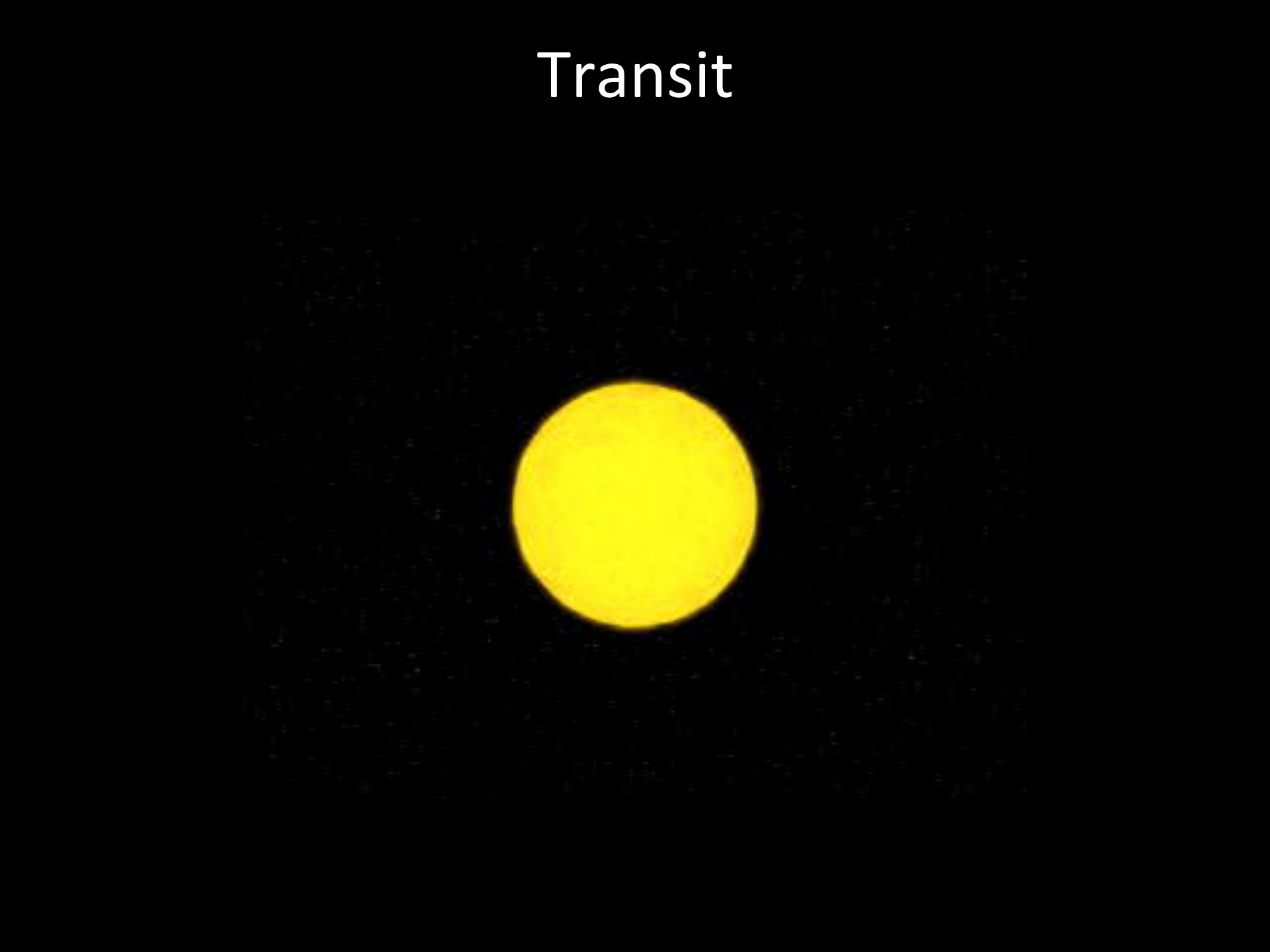


Warm Neptune (GJ 1214b, GJ 436b)

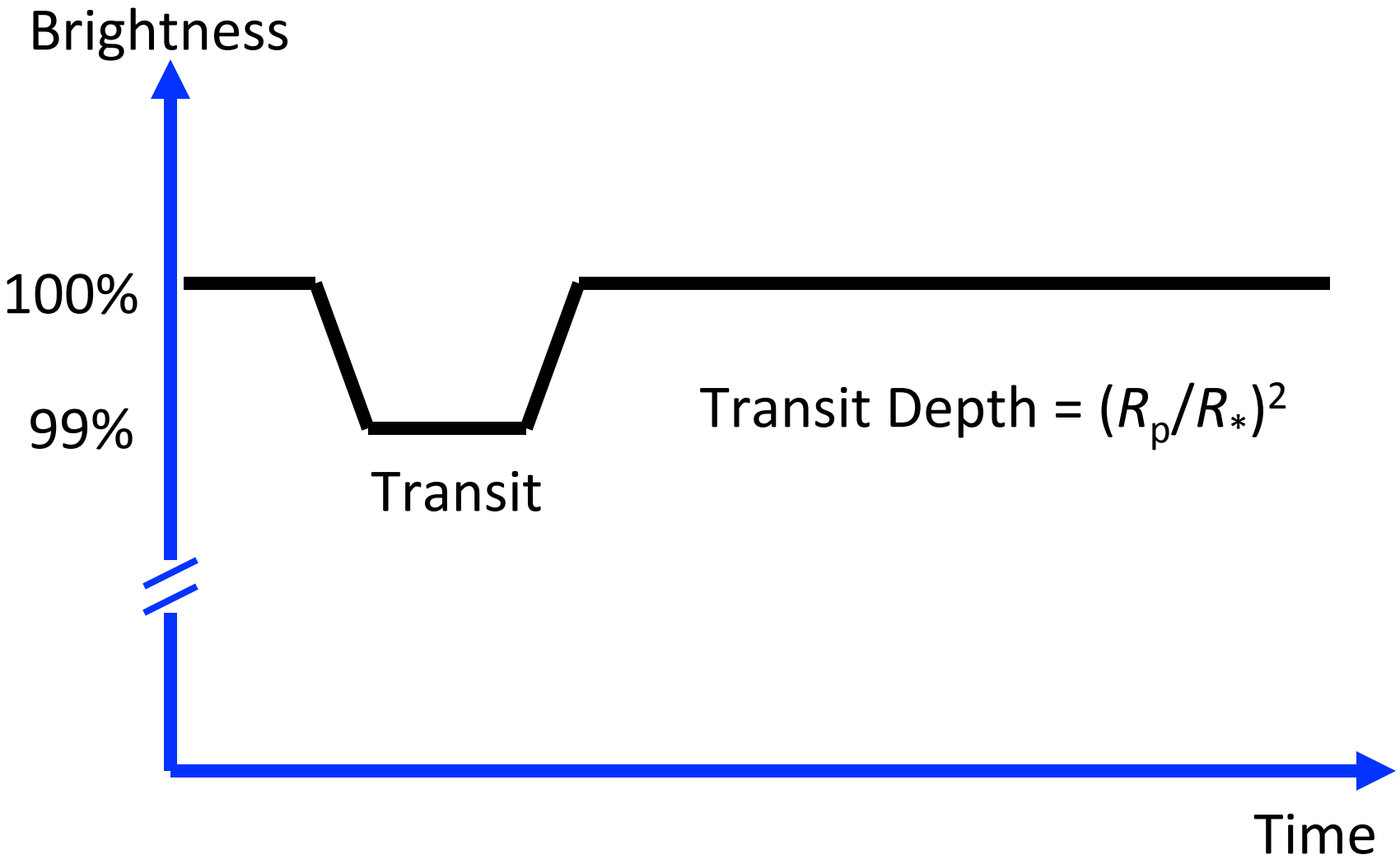


Hot Jupiter (HD 209458b, HD 189733b, WASP-12b)

Transit

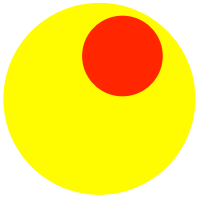


Thermal Light Curve

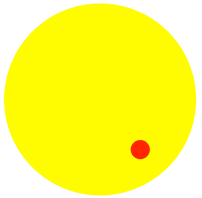


Some Transit Depths

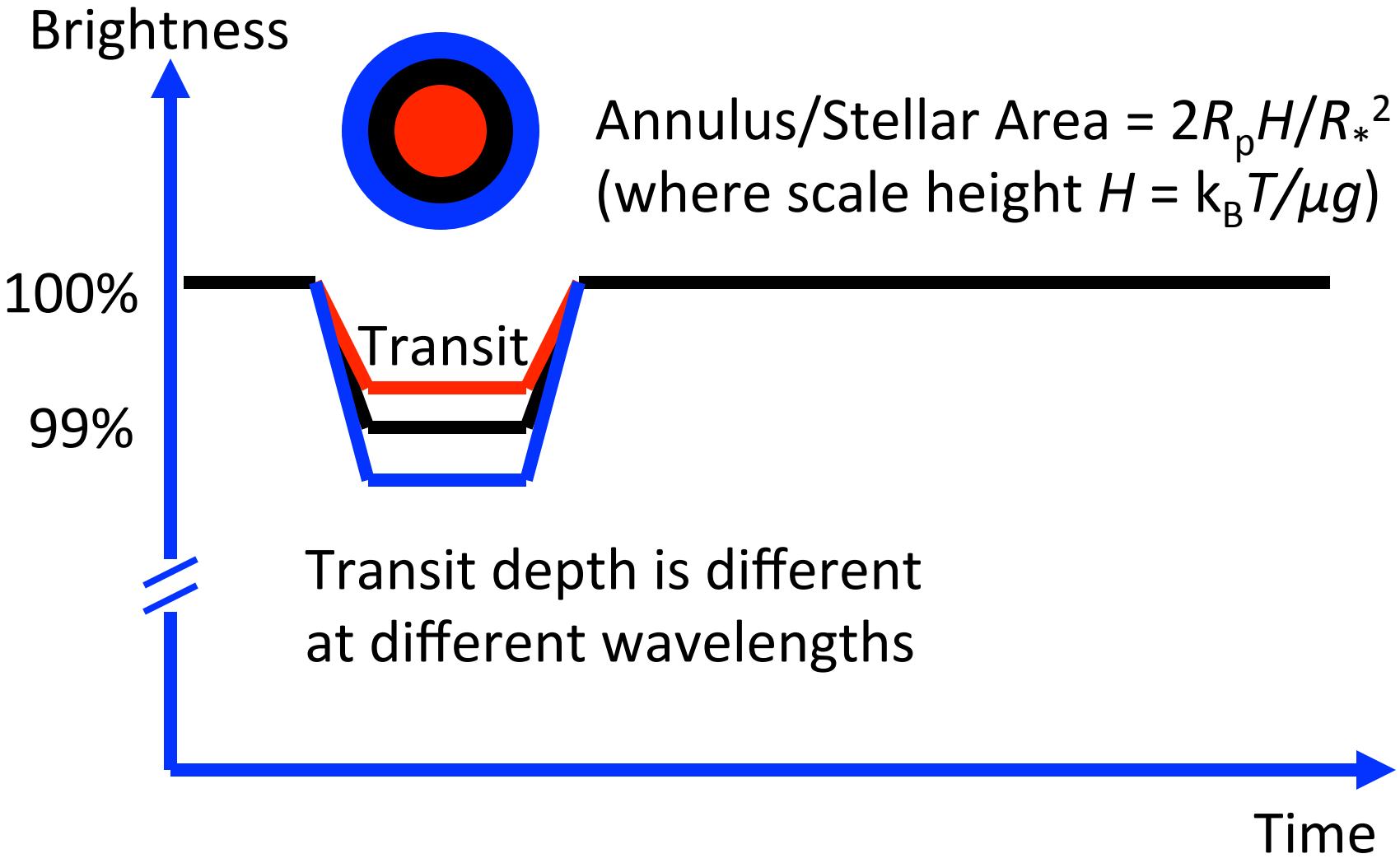
Warm Neptune: 2.7E-2 

Hot Jupiter: 8.8E-3 

Temperate Super-Earth: 7.3E-3 

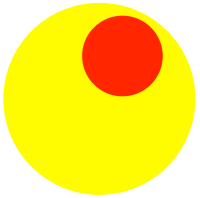
Hot Earth: 7.3E-5 

Thermal Light Curve

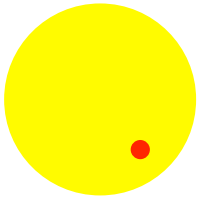


Some Transit Spectral Features

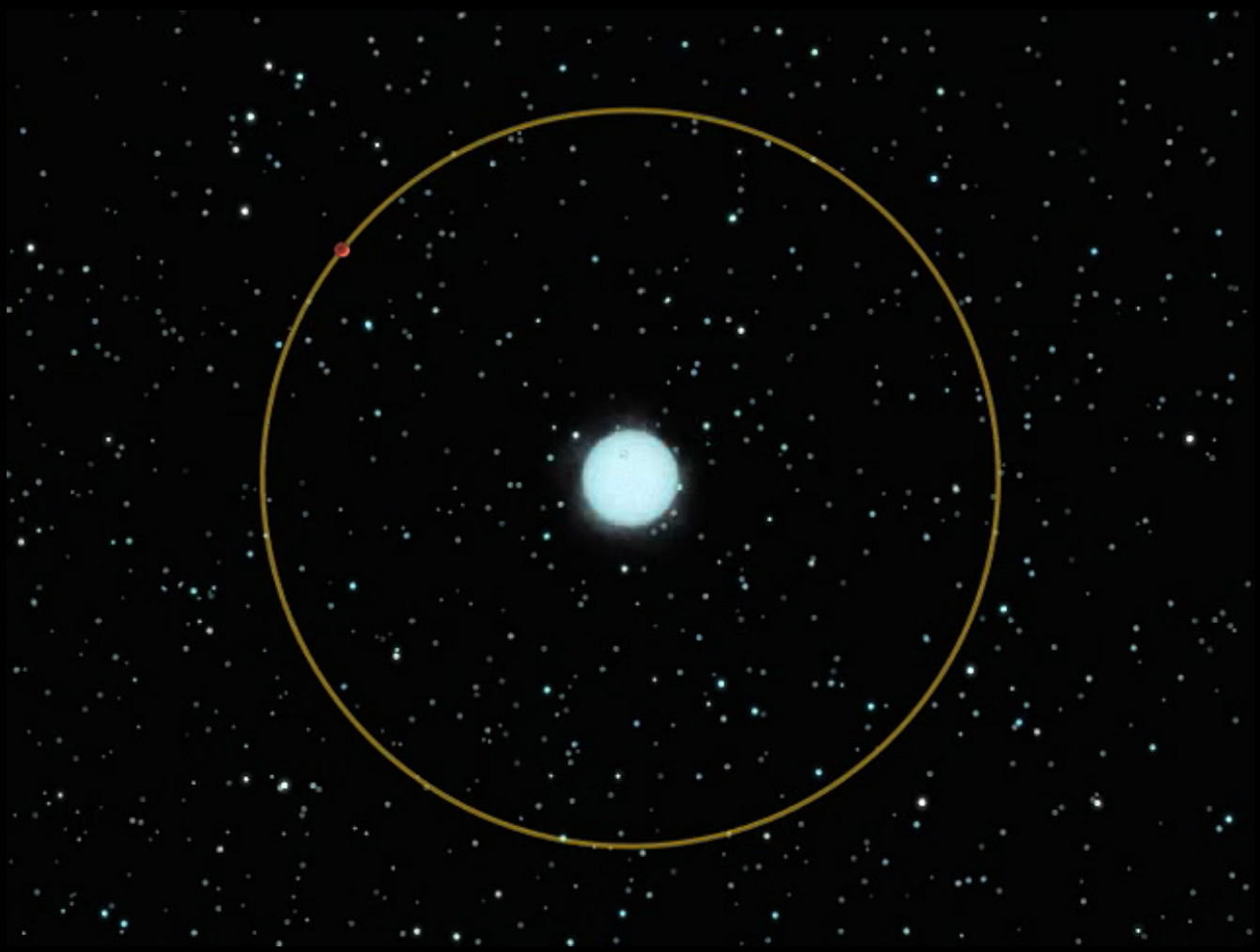
Warm Neptune: 2.4E-4 

Hot Jupiter: 1.2E-4 

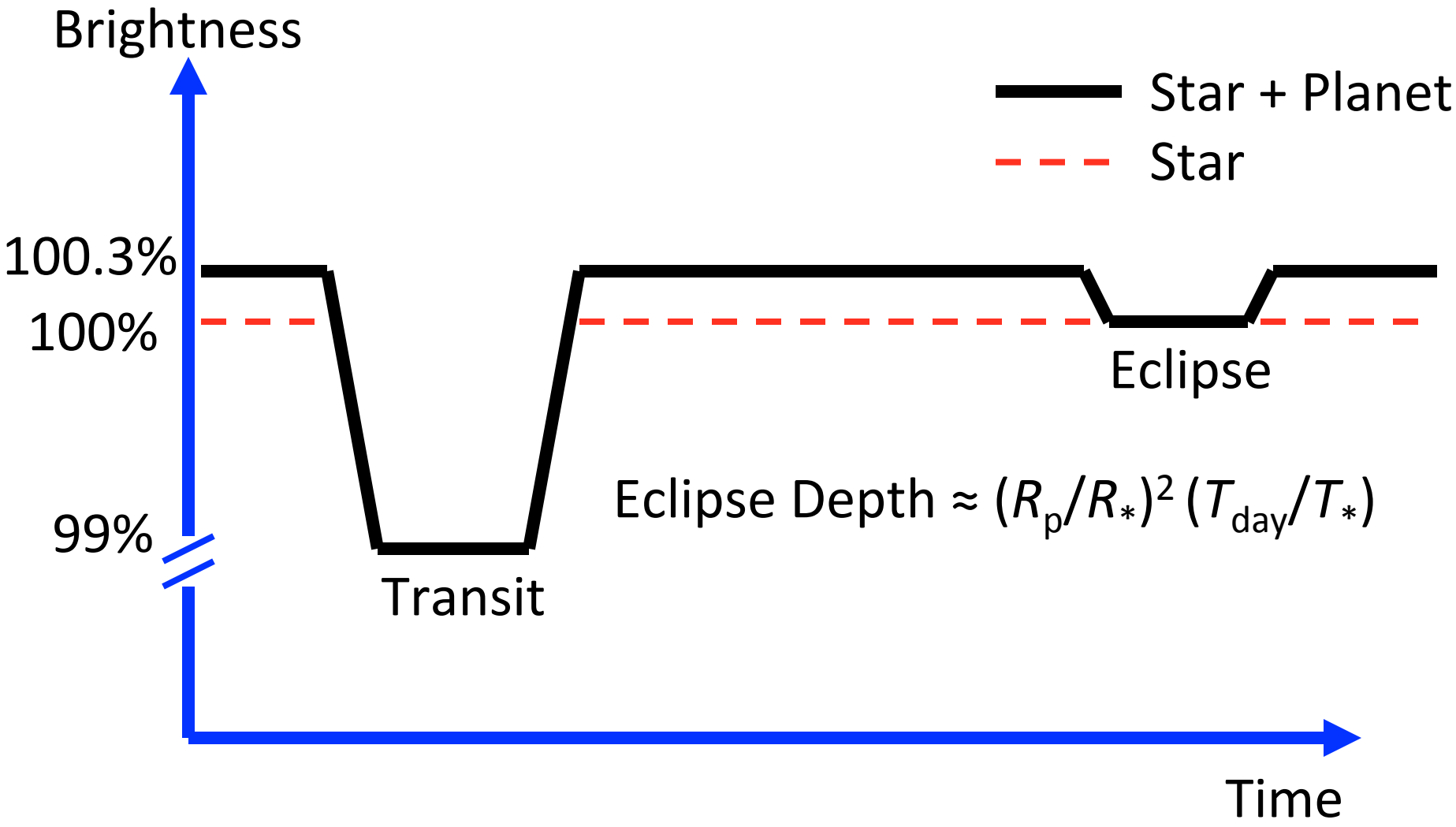
Temperate Super-Earth: 6.5E-6 

Hot Earth: 2.0E-6 

Eclipse

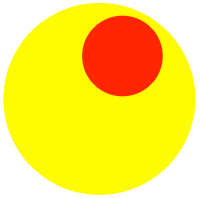


Thermal Light Curve

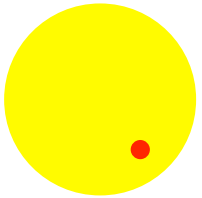


Some Eclipse Depths

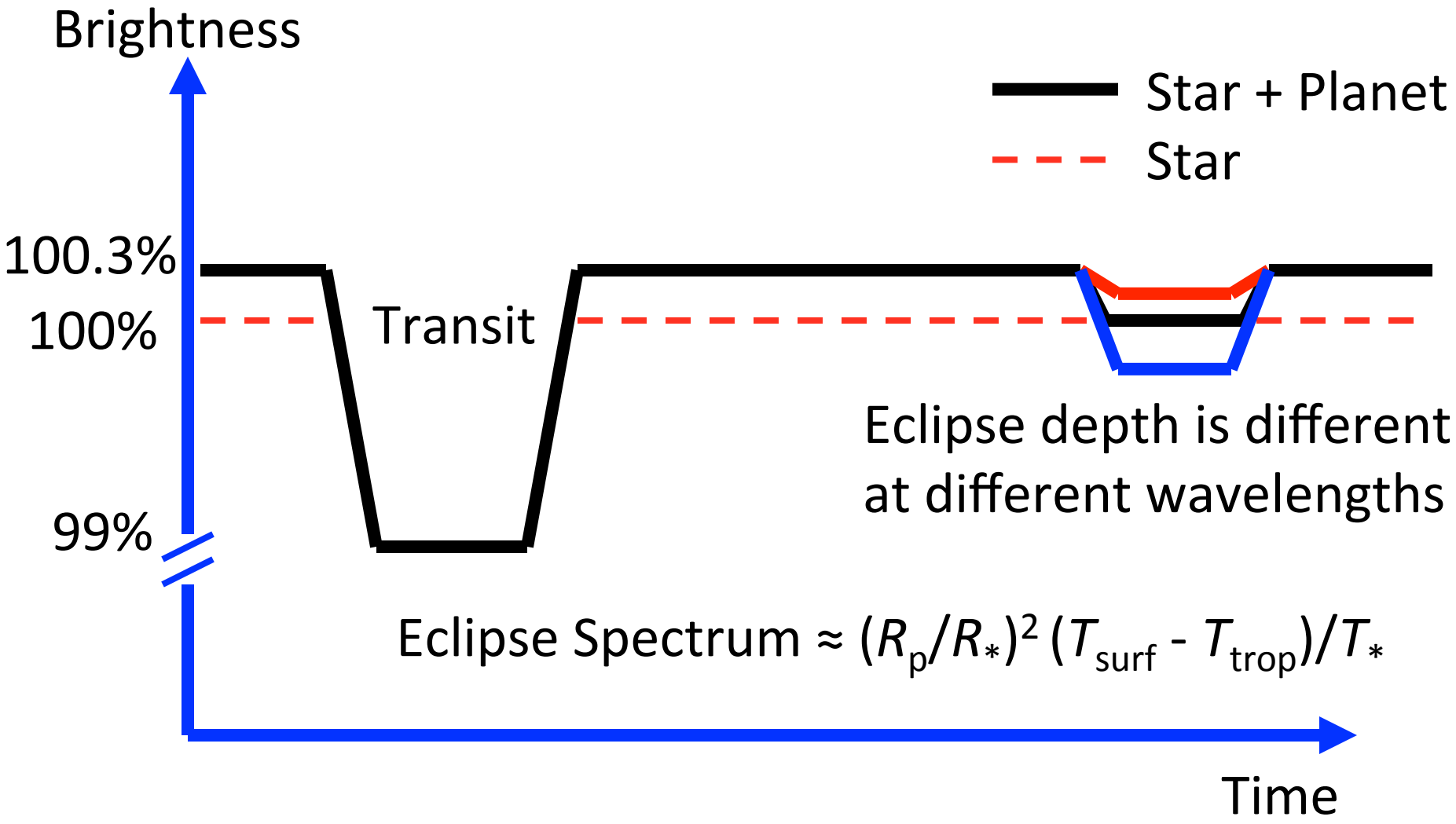
Warm Neptune: 8.1E-3 

Hot Jupiter: 4.0E-3 

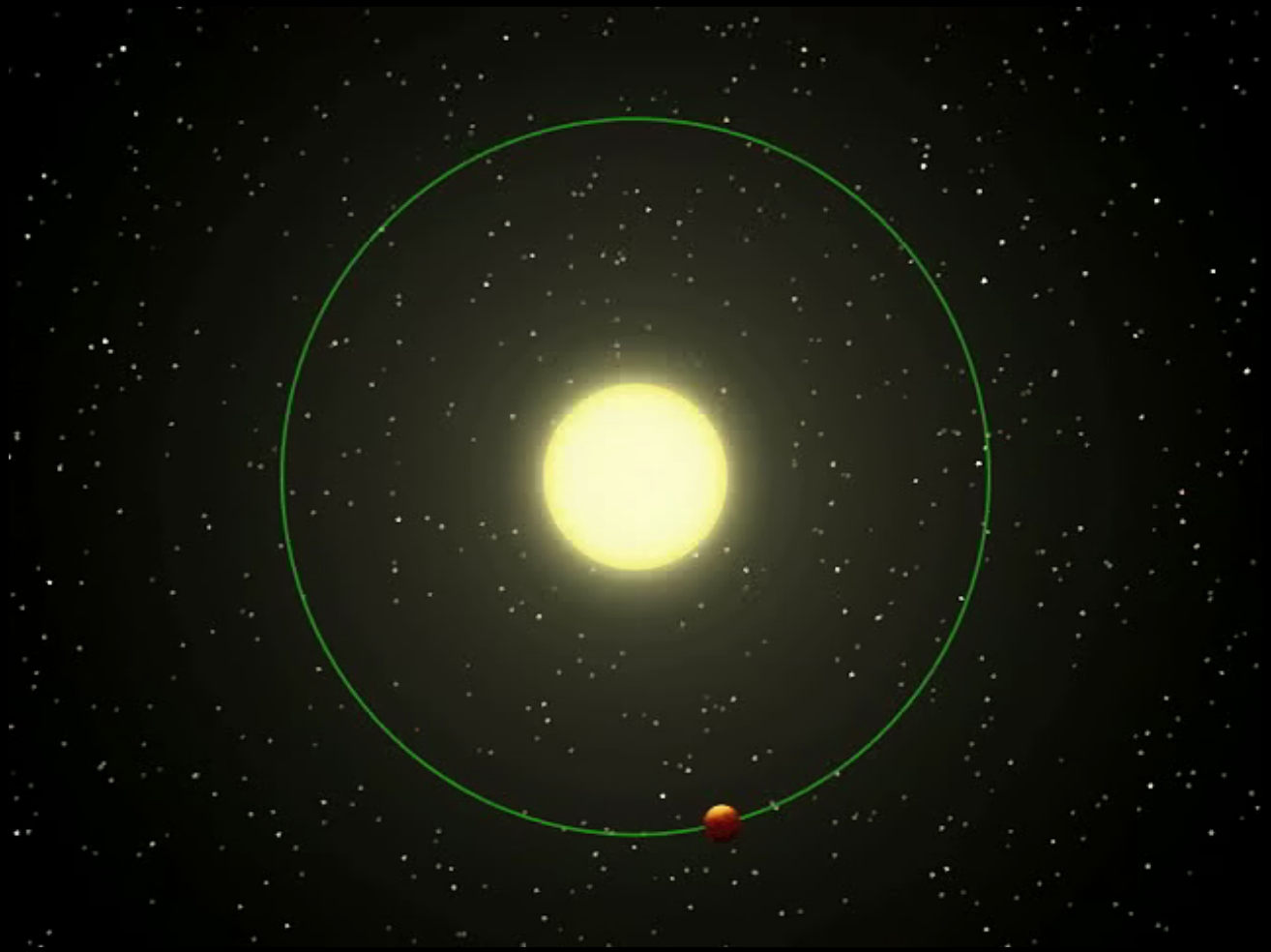
Temperate Super-Earth: 7.0E-4 

Hot Earth: 3.3E-5 

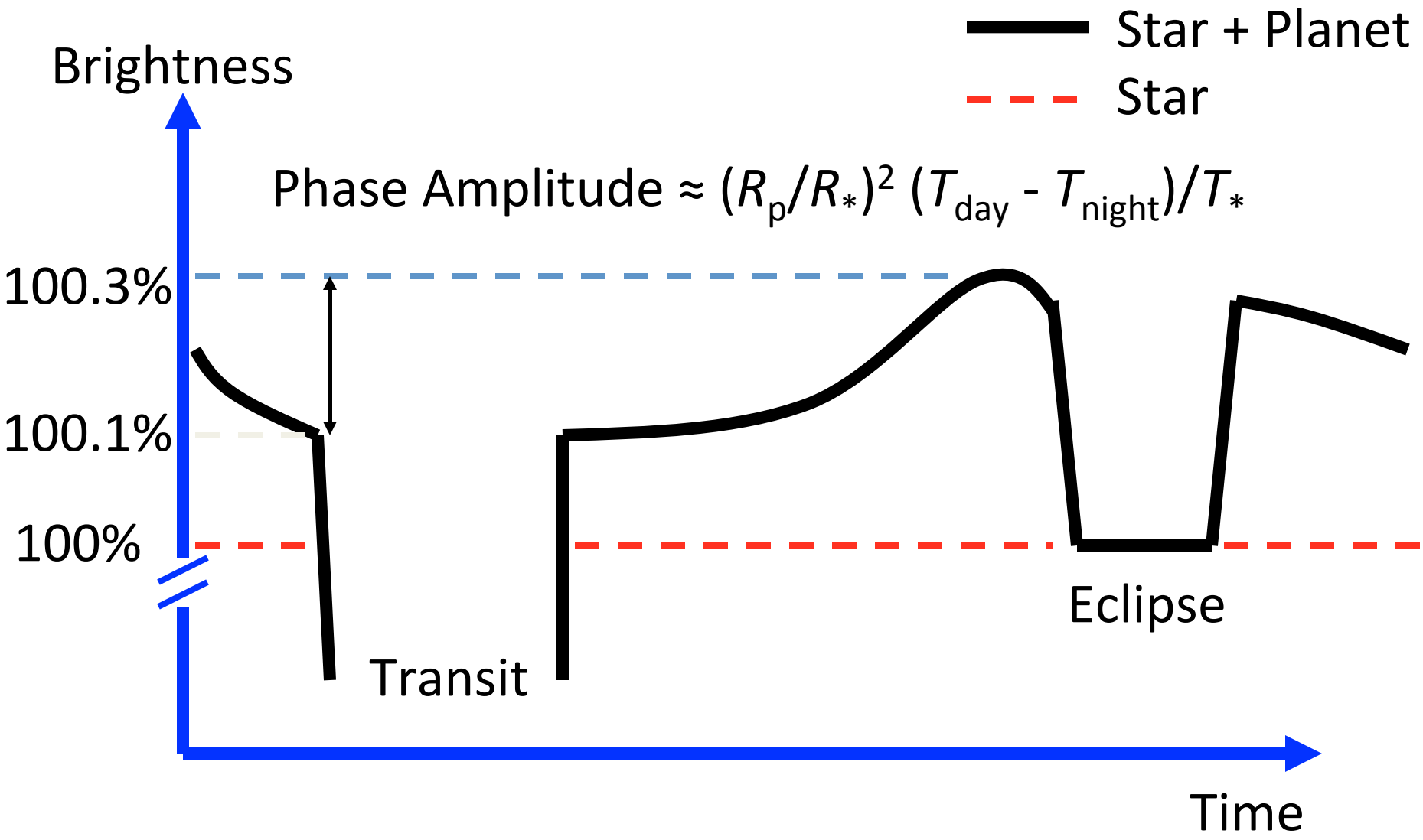
Thermal Light Curve



Thermal Phases



Thermal Light Curve



Eclipse Spectroscopy vs. Phase Variations

- Differences in temperature
  - Vertical (33-200 K)
  - Zonal (60-2000 K)
- Spectroscopy has to achieve S/N with relatively narrow bandwidth (R>10)
- Phase variations require long-term stability

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