Phase Variations of Imaged Planets

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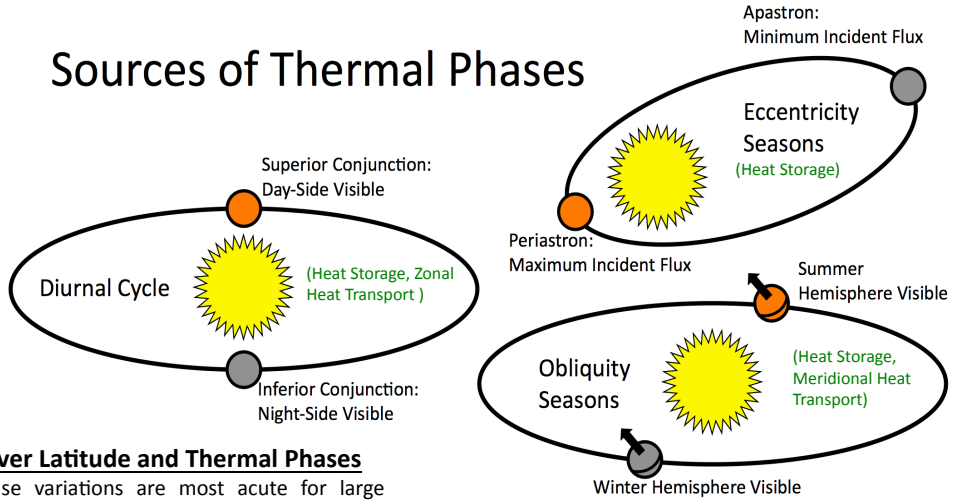
Introduction

An extrasolar planet's disk-averaged apparent albedo and emitting temperature change as a function of its orbital location, a phenomenon known as phase variations. The reflected light variations are governed by scattering phase functions, as well as seasonal and diurnal changes in albedo. The thermal phase variations are affected by a planet's climate, rotational and orbital parameters.

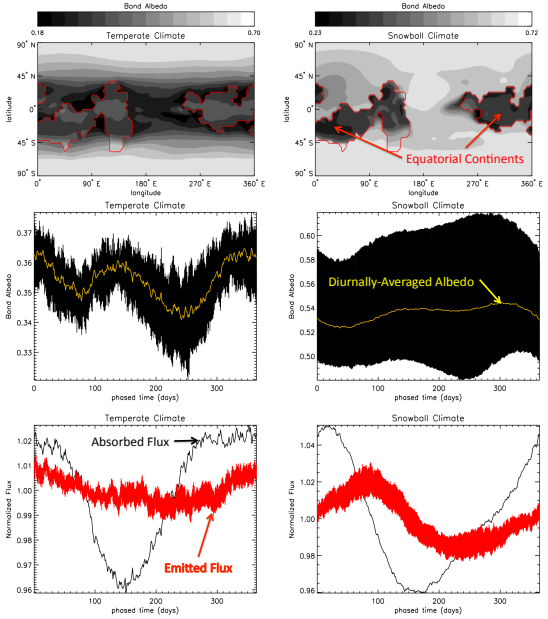
We use the global climate models of Voigt et al. (2011) to calculate reflected and thermal phase variations for an Earth-like planet in temperate and snowball climate states. These are essentially predictions of what we will see when we monitor nearby Habitable Zone planets with a Terrestrial Planet Finder Coronagraph/Occulter (TPF-C/O) or a Terrestrial Planet Finder Interferometer (TPF-I).

Sources of Thermal Phases



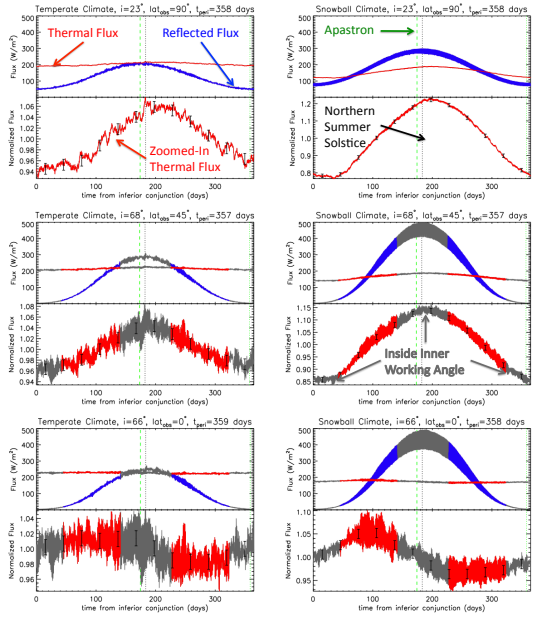
1) Climate and Thermal Inertia

A snowball planet has globally frozen oceans, leading to increased albedo (ice is more reflective than water) and reduced thermal inertia (ice mixes less well than water). Seasonal changes in albedo combine with a planet's eccentric orbit to modulate its absorbed power budget. The planet's thermal inertia dictates how the thermal radiation responds to the varying absorbed power.



2) Observer Latitude and Thermal Phases

Thermal phase variations are most acute for large observer latitudes, when the phase variations are dominated by obliquity seasons. For more equatorial viewing geometries, the eccentricity seasons and diurnal cycle dominate, so the argument of periastron is the critical variable. The snowball planet exhibits stronger obliquity seasons, both because of reduced thermal inertia, and reduced N-S ocean heat transport.



3) Observer Latitude and Reflected Phases

Reflected phase variations are mostly governed by the planet's orbital phase. This dependence can be factored out by expressing the phase variations as an apparent albedo. The apparent albedo exhibits high-frequency rotational variability due to surface features coming in and out of view; this effect is greater for the snowball planet because of reduced cloud cover. The apparent albedo also exhibits phase variations because of the varying latitude and shape of the contribution function (illumination × visibility). This phenomenon will throw off attempts to infer glinting liquid water oceans from their effect on a planet's reflected phase variations.