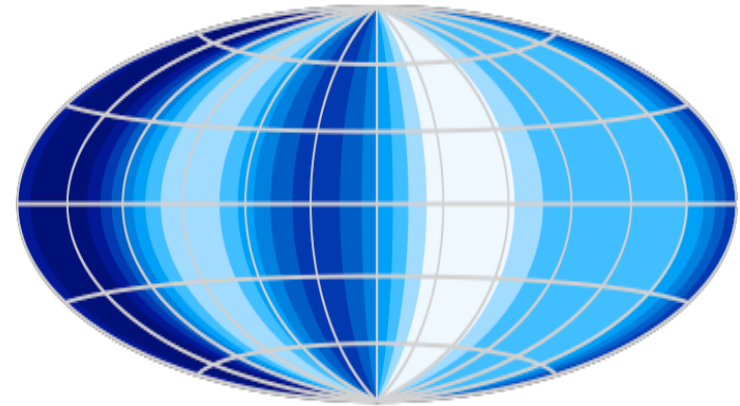
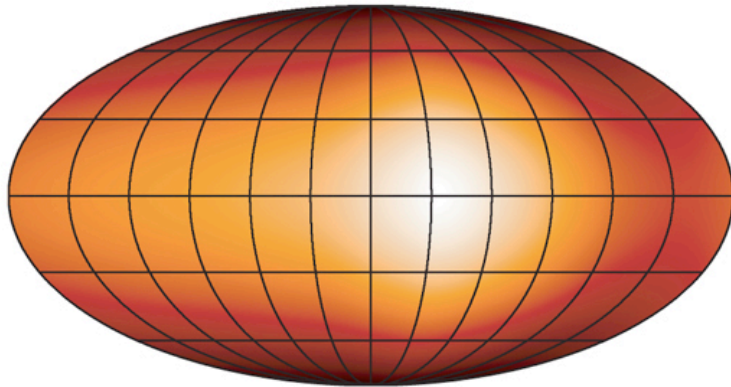


Exo-Cartography

(Mapping the Climate and Surface of Exoplanets)

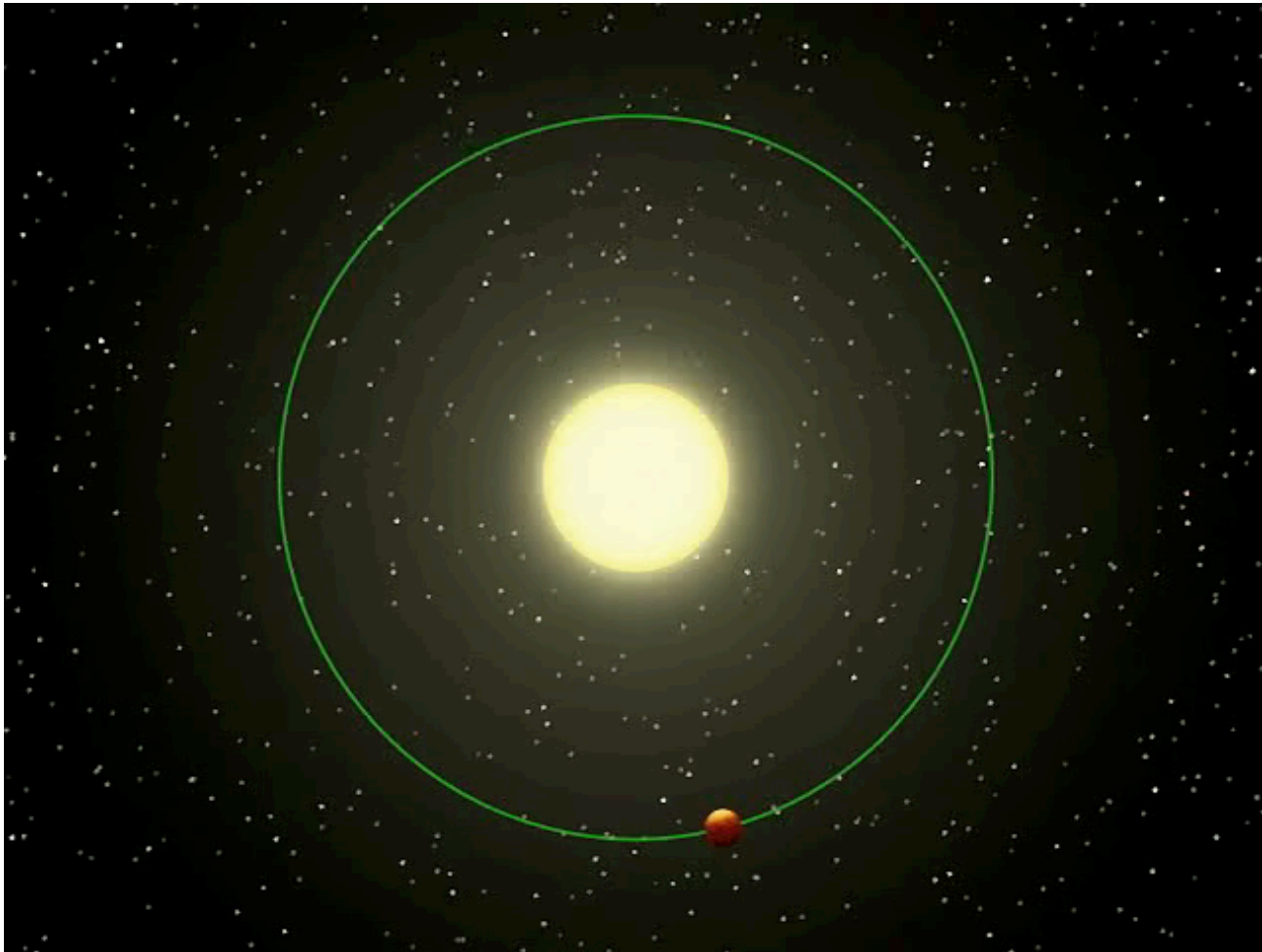


Nick Cowan

CIERA Fellow, Northwestern University

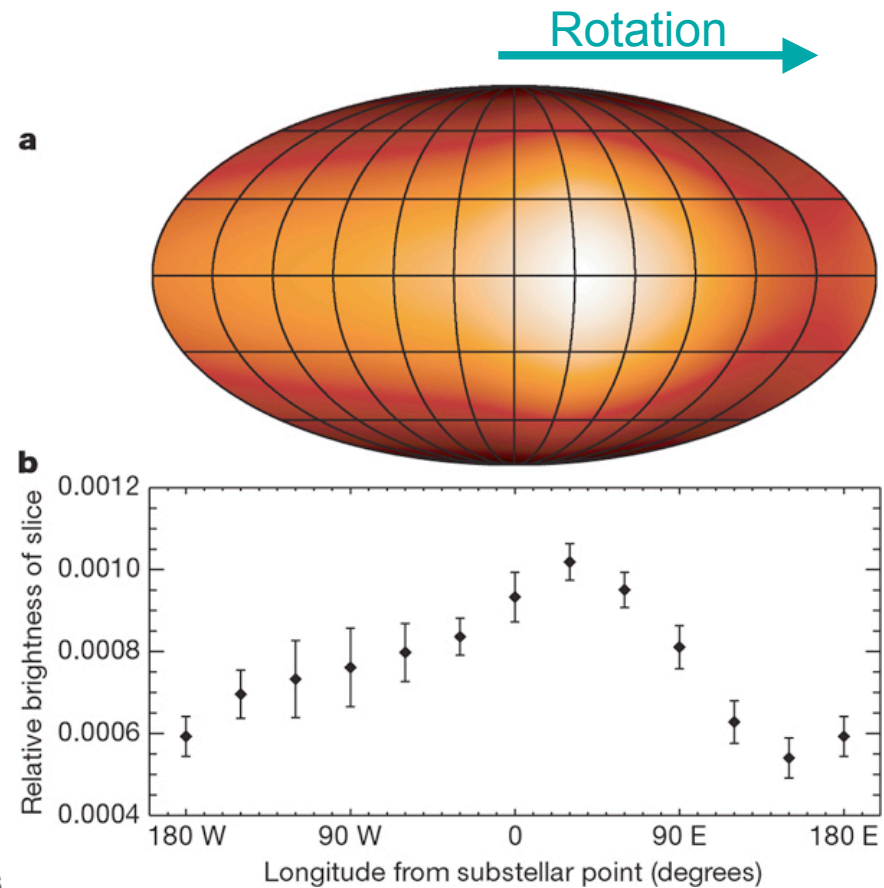
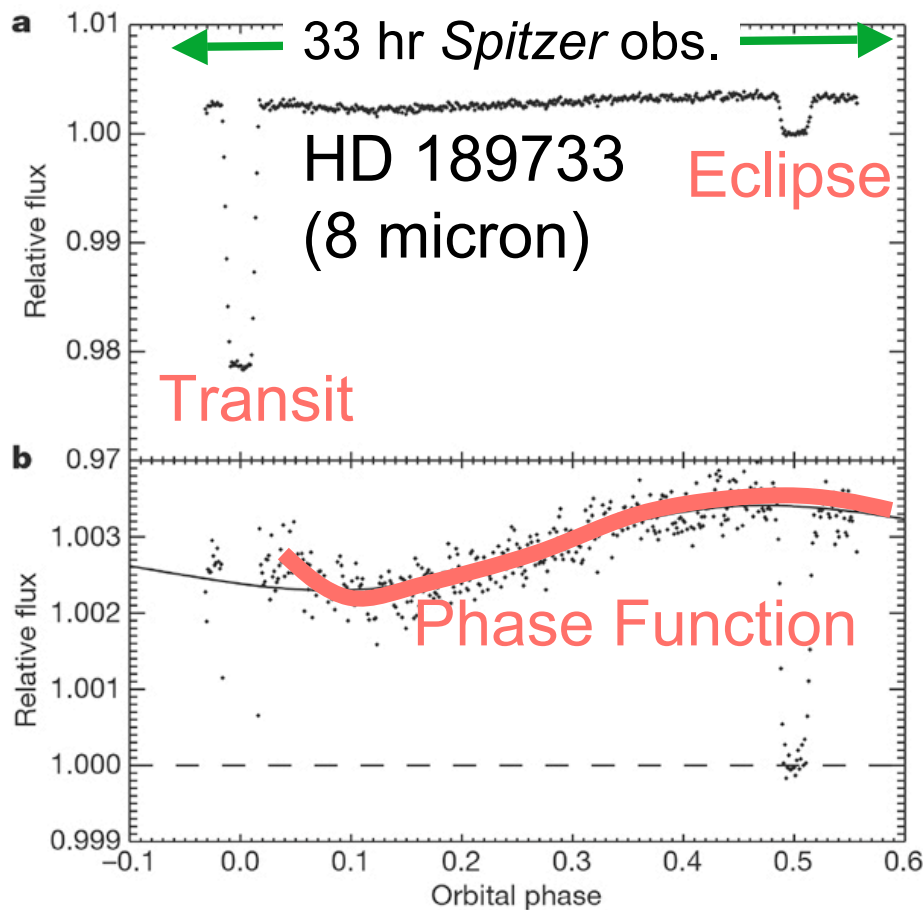
ExoClimes, Sept 9 2010

Thermal Phases



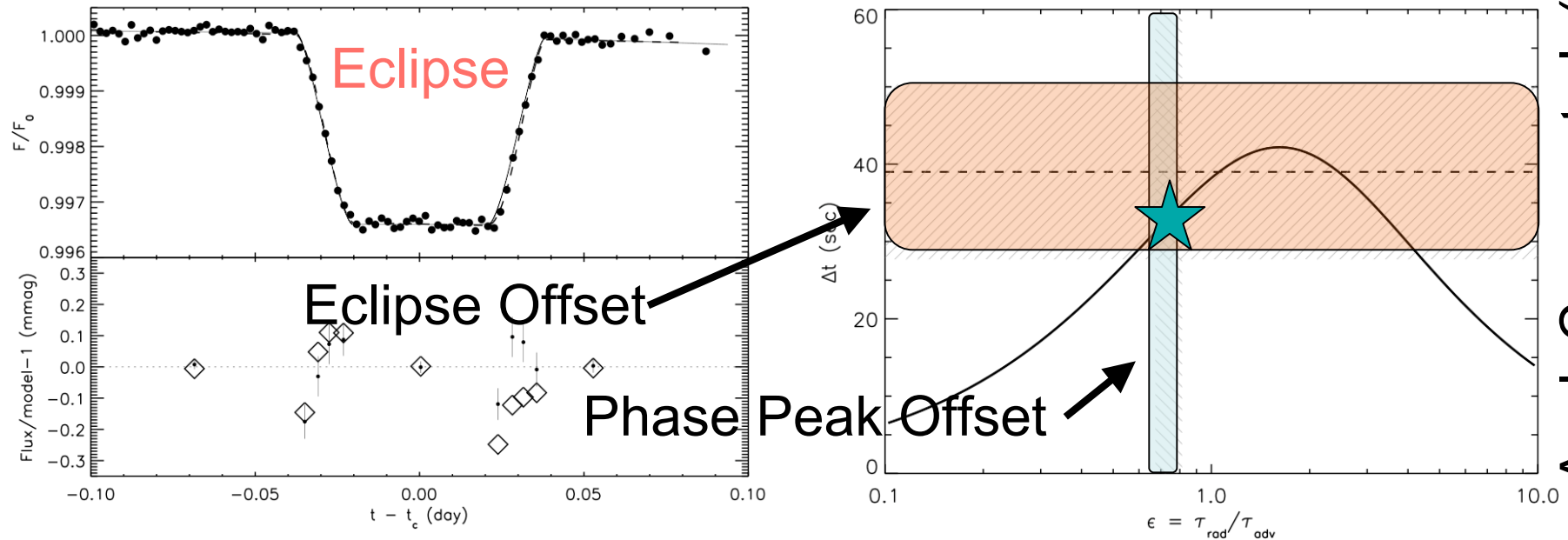
Phase Mapping

(Knutson et al. 2007, Cowan & Agol 2008)



Eclipse Mapping

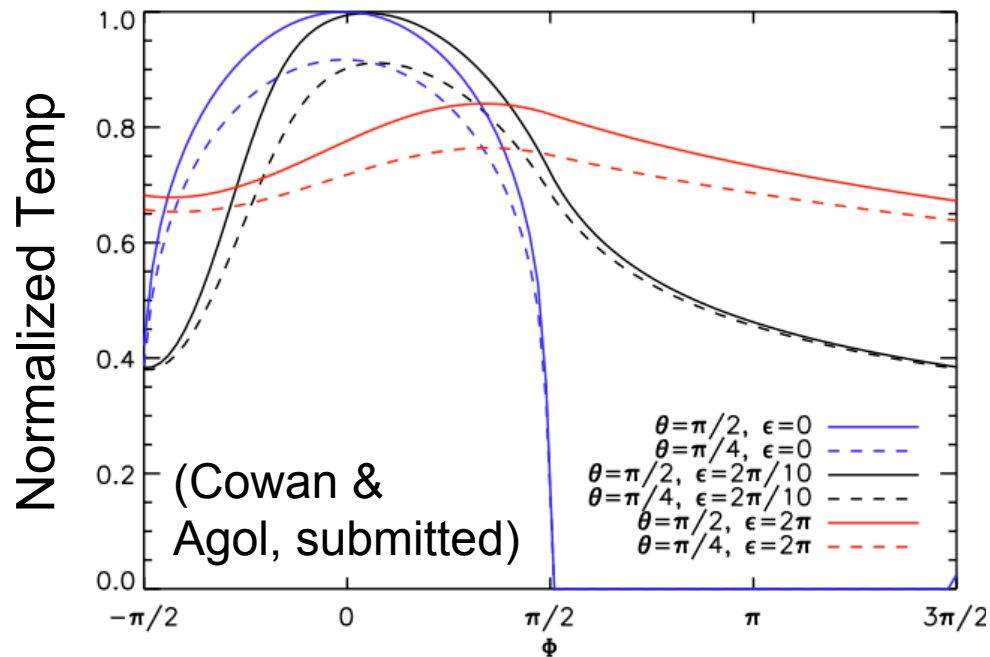
- Timing and shape of ingress/egress is sensitive to *longitudinal and latitudinal* flux distribution of planet's day-side (Williams et al. 2006, Rauscher et al. 2007)



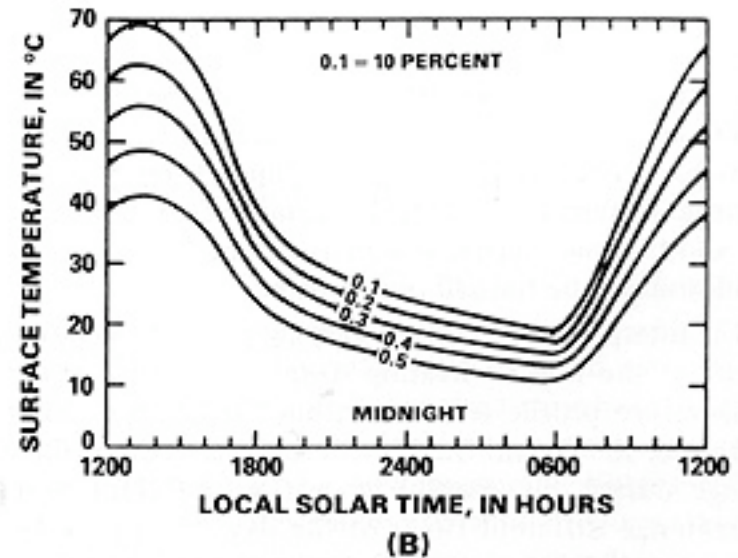
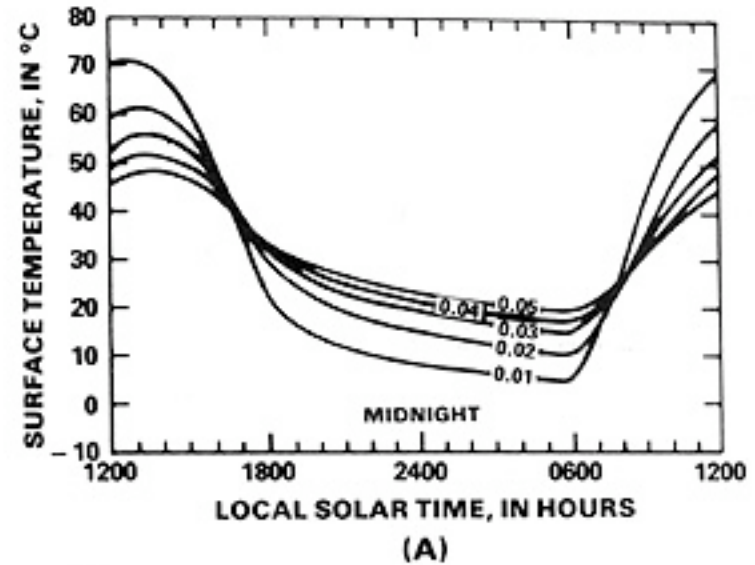
Agol, Cowan et al. (2010)

Stack seven *Spitzer* 8-micron eclipses of HD 189733b.
 ~40 sec discrepancy in time of eclipse constrains hot spot.

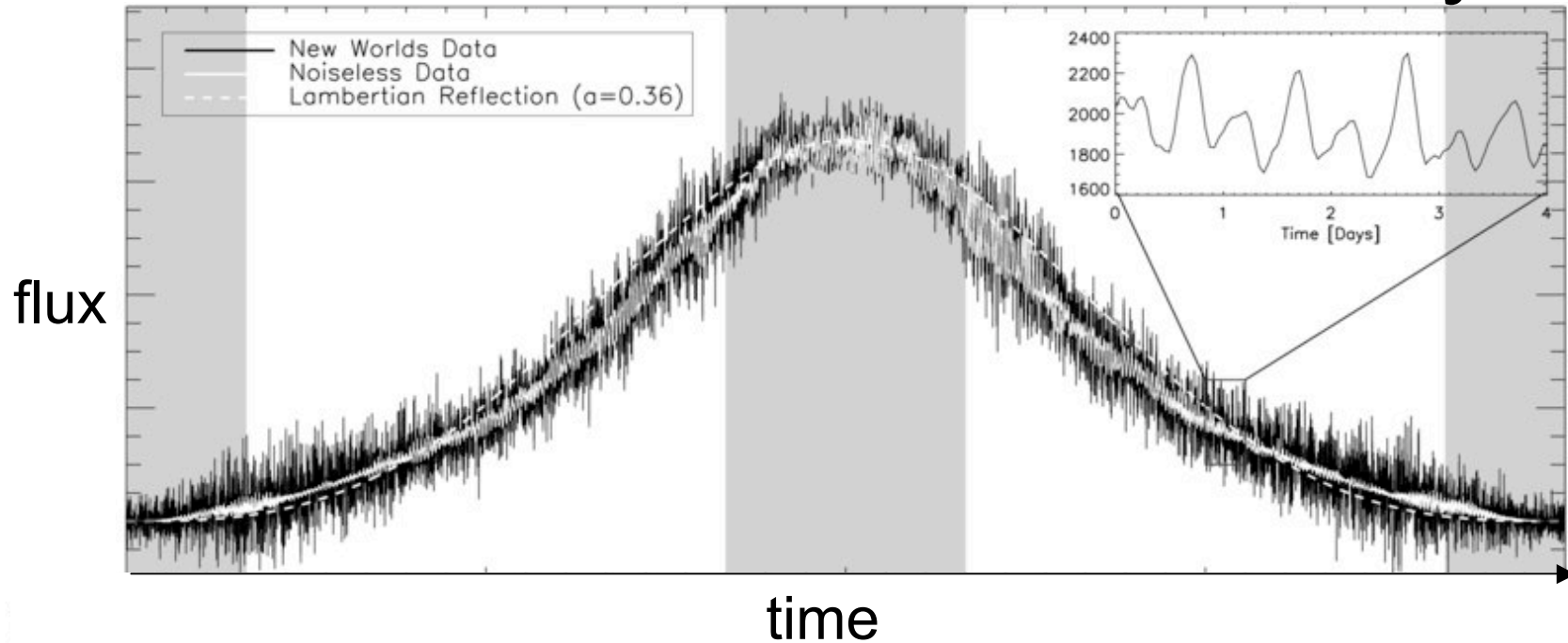
Diurnal Temperature Cycle



Thermal phase variations constrain: thermal inertia, albedo, rotation, wind, emissivity, etc.

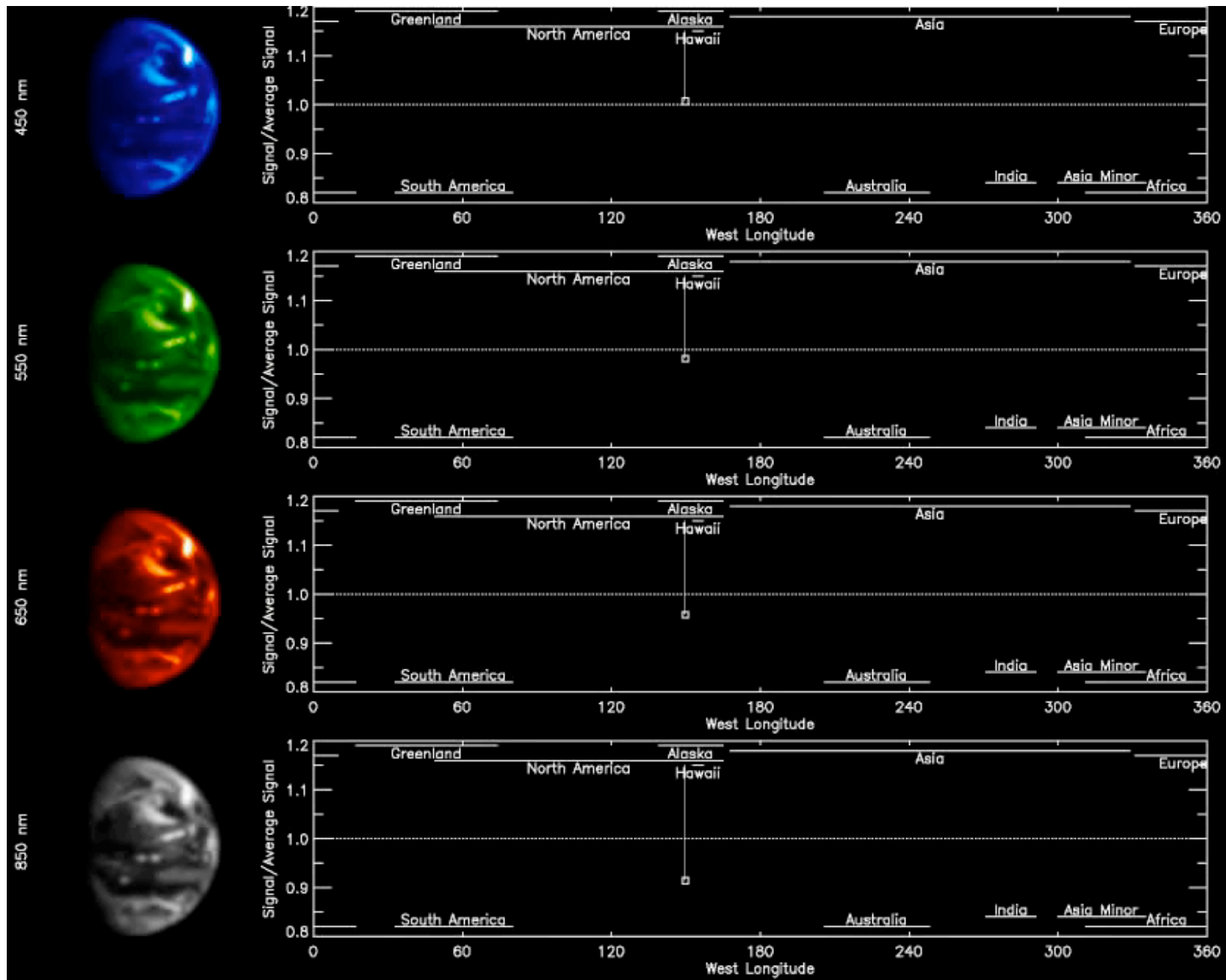


Reflected Lightcurve: Orbital & Rotational Variability



(Oakley & Cash 2009)

- 1) Characterize phase function (Williams & Gaidos 2008, Robinson et al. 2010)
- 2) Polarization phase function (Zugger et al. 2010)
- 3) Establish rotation rate (Palle et al. 2008, Oakley & Cash 2009)
- 4) Characterize rotational variability (Ford, Seager & Turner 2001)

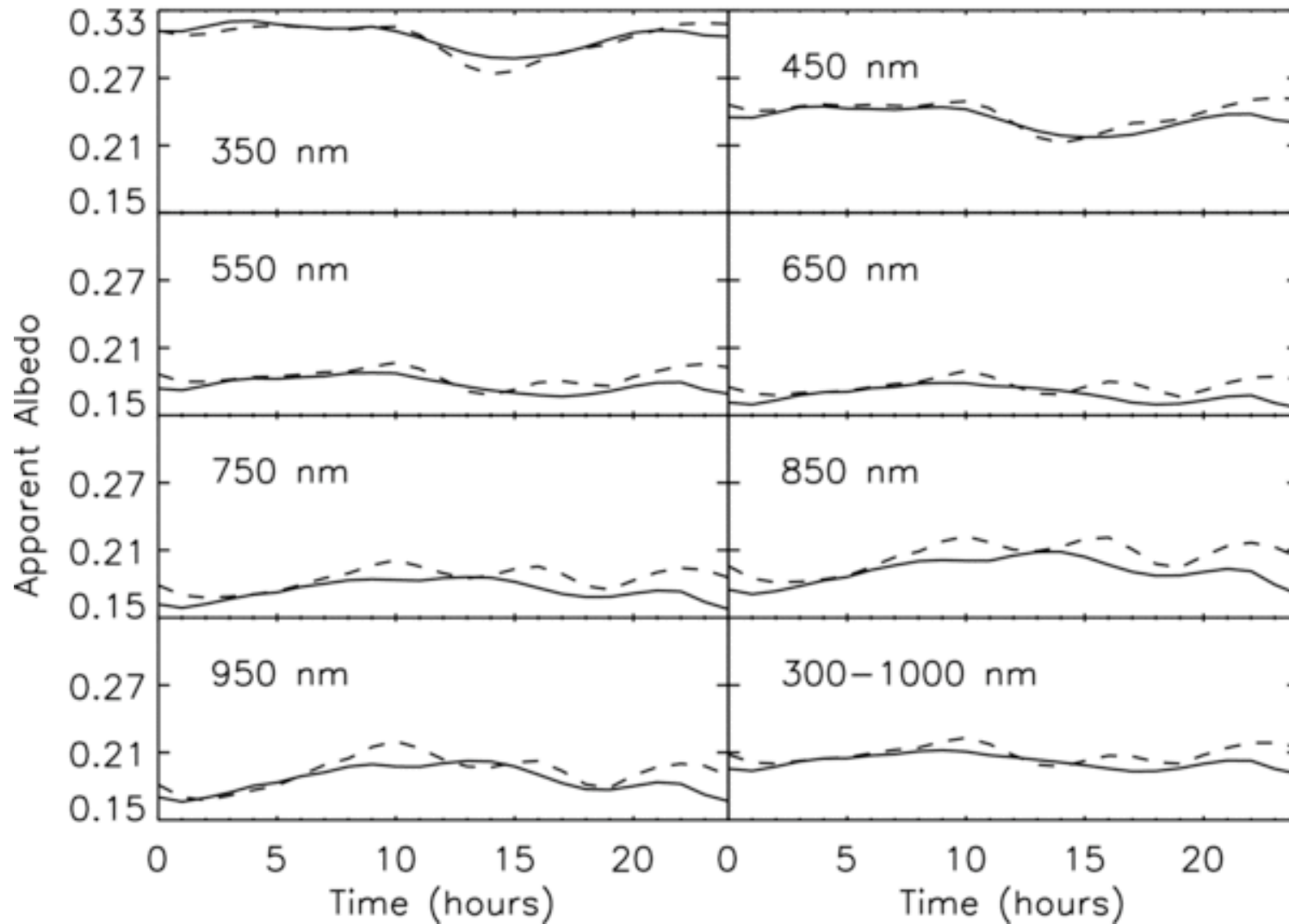


Sept 9, 2010

Nick Cowan's talk at ExoClimes

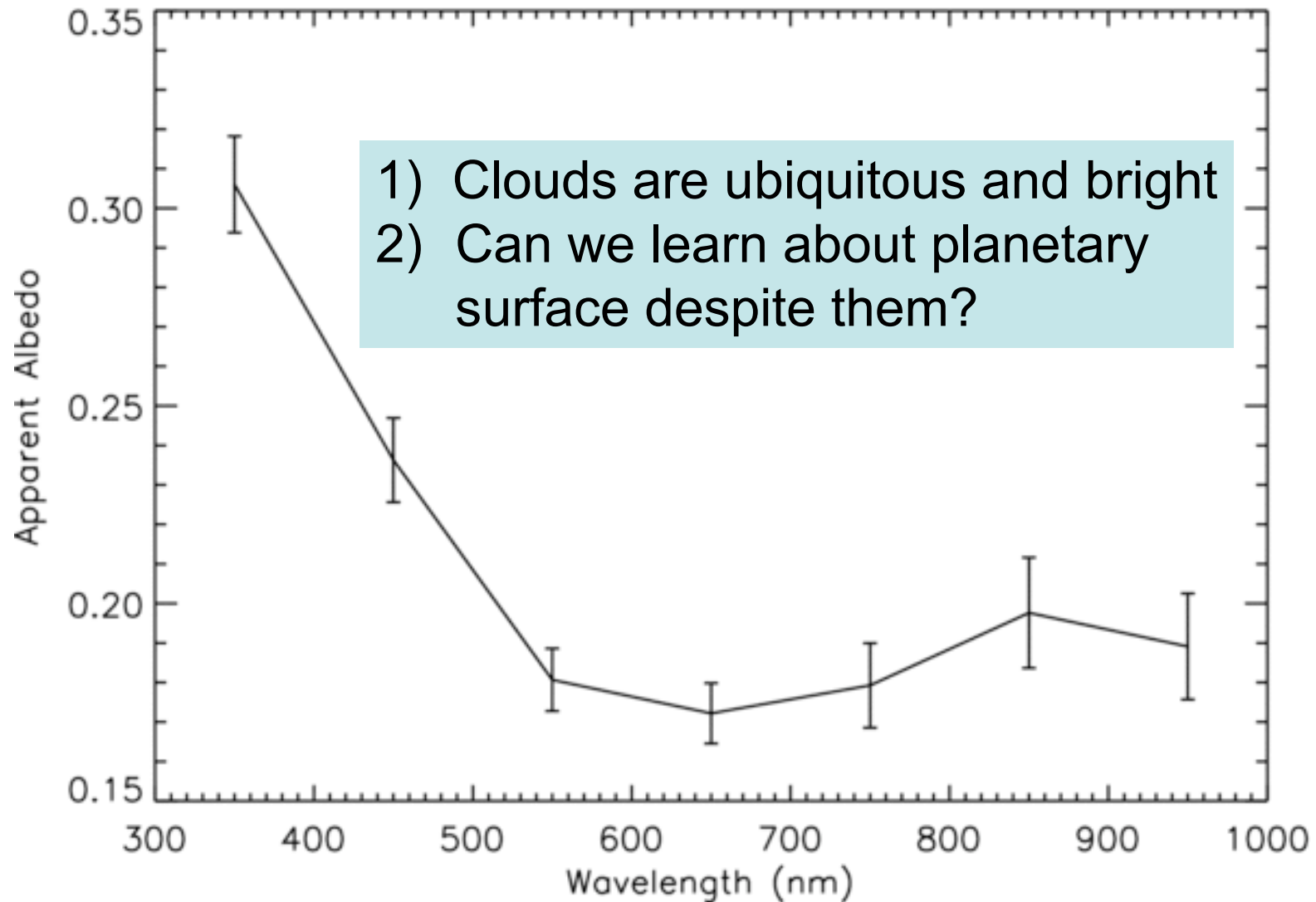
7

EPOXI Light Curves



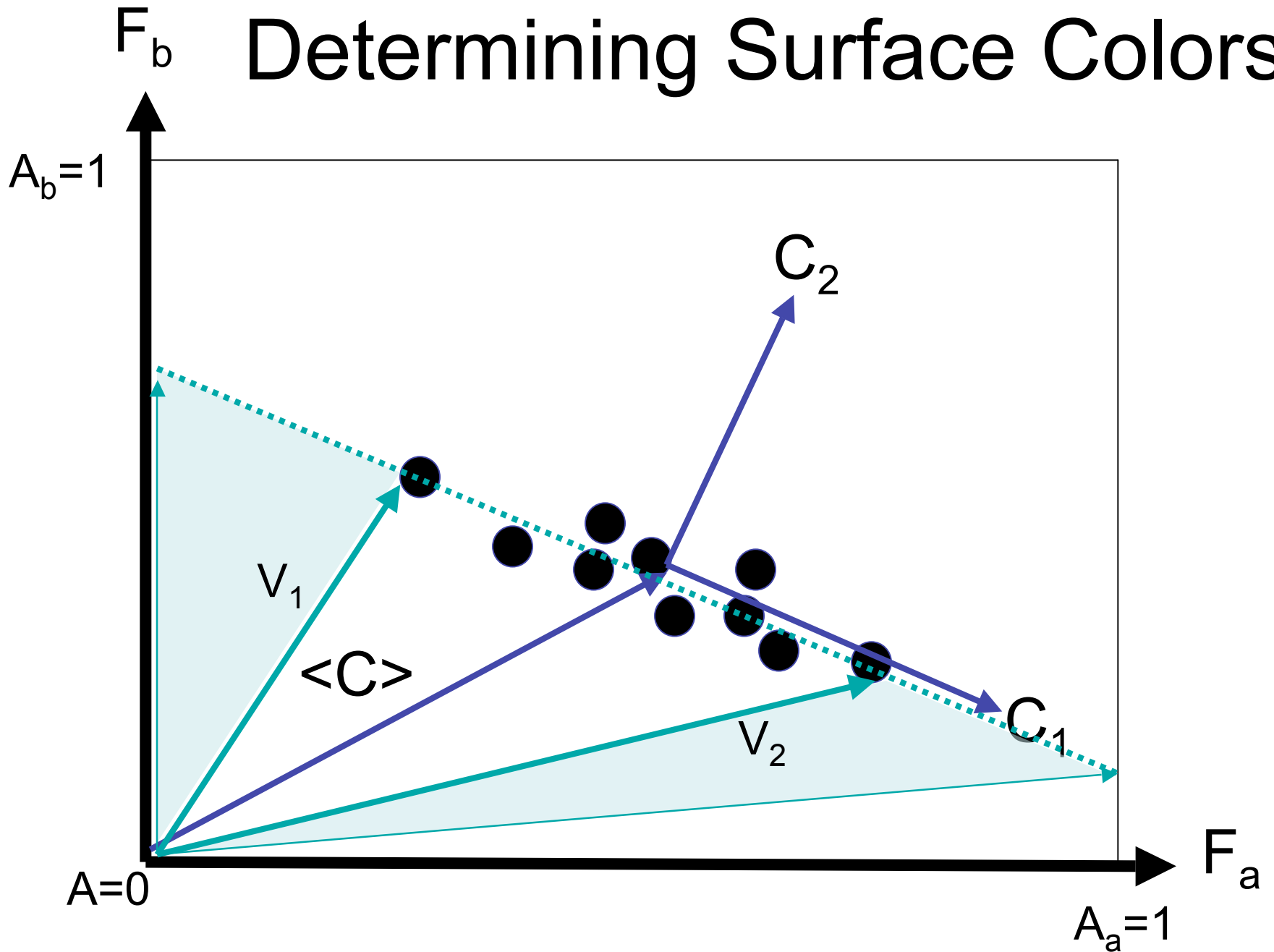
Cowan et al. (2009)

Time-Averaged Spectrum

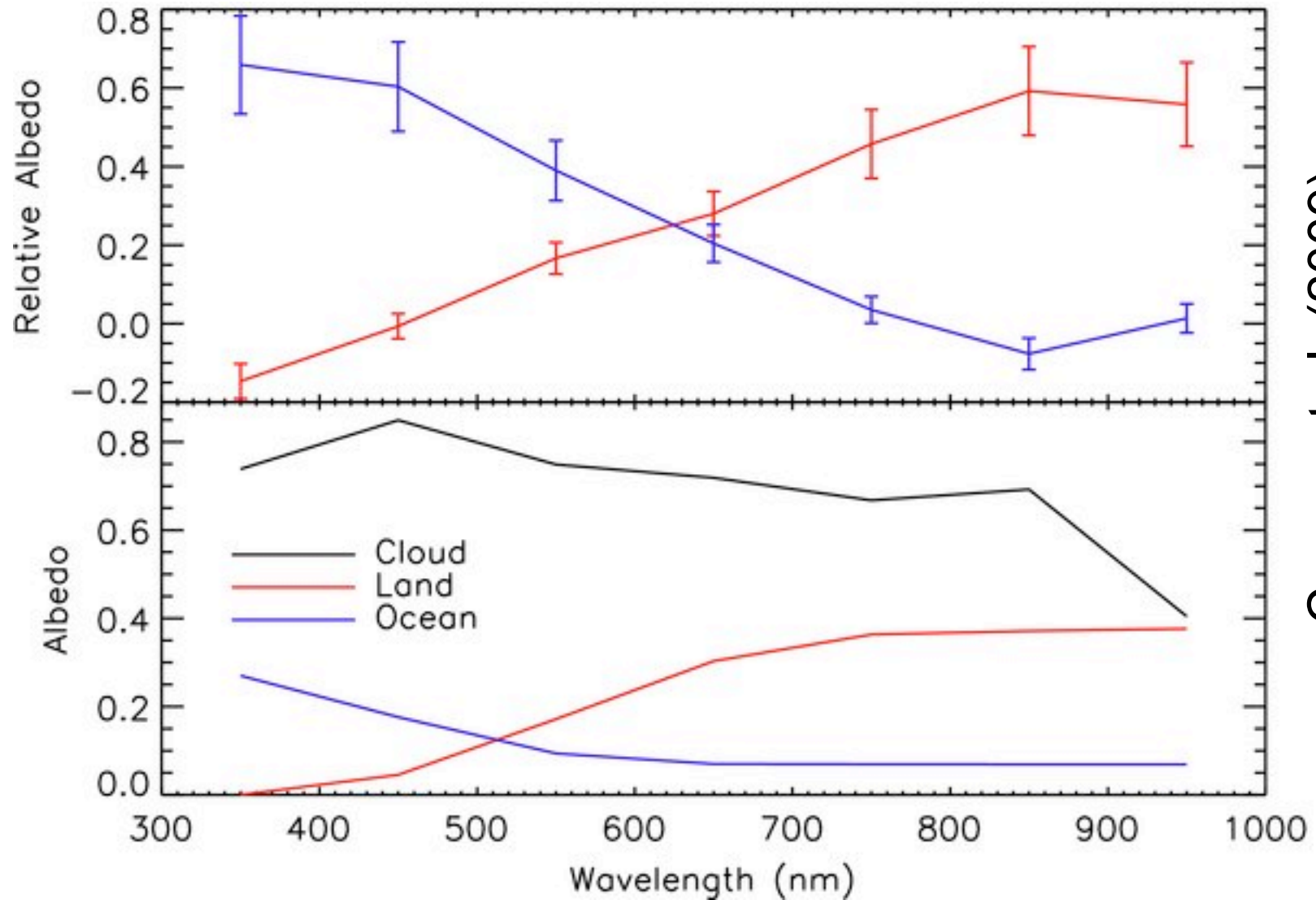


Cowan et al. (2009)

Determining Surface Colors

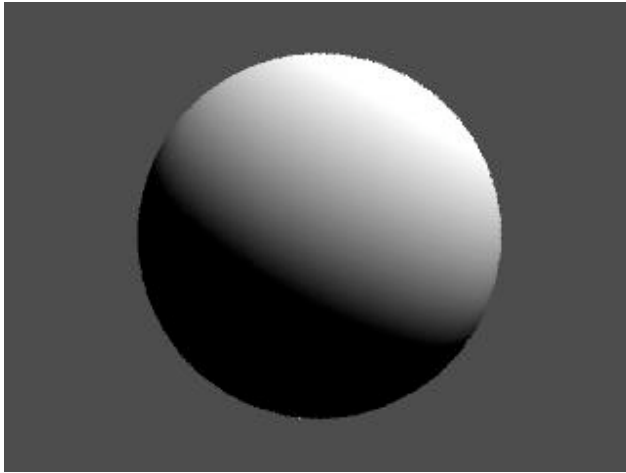


Eigencolors

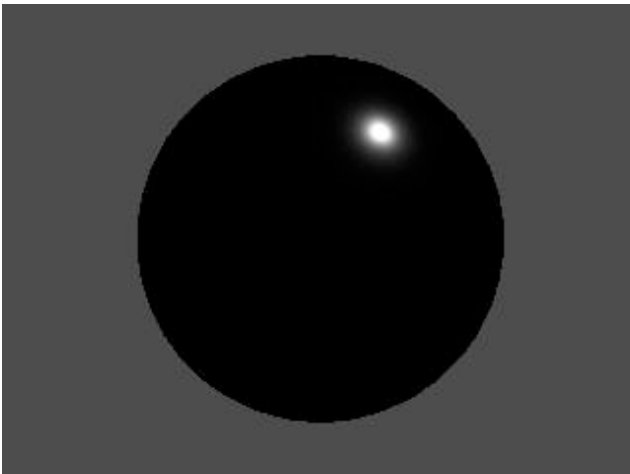


Cowan et al. (2009)

Reflected Light (Analytic Limits)

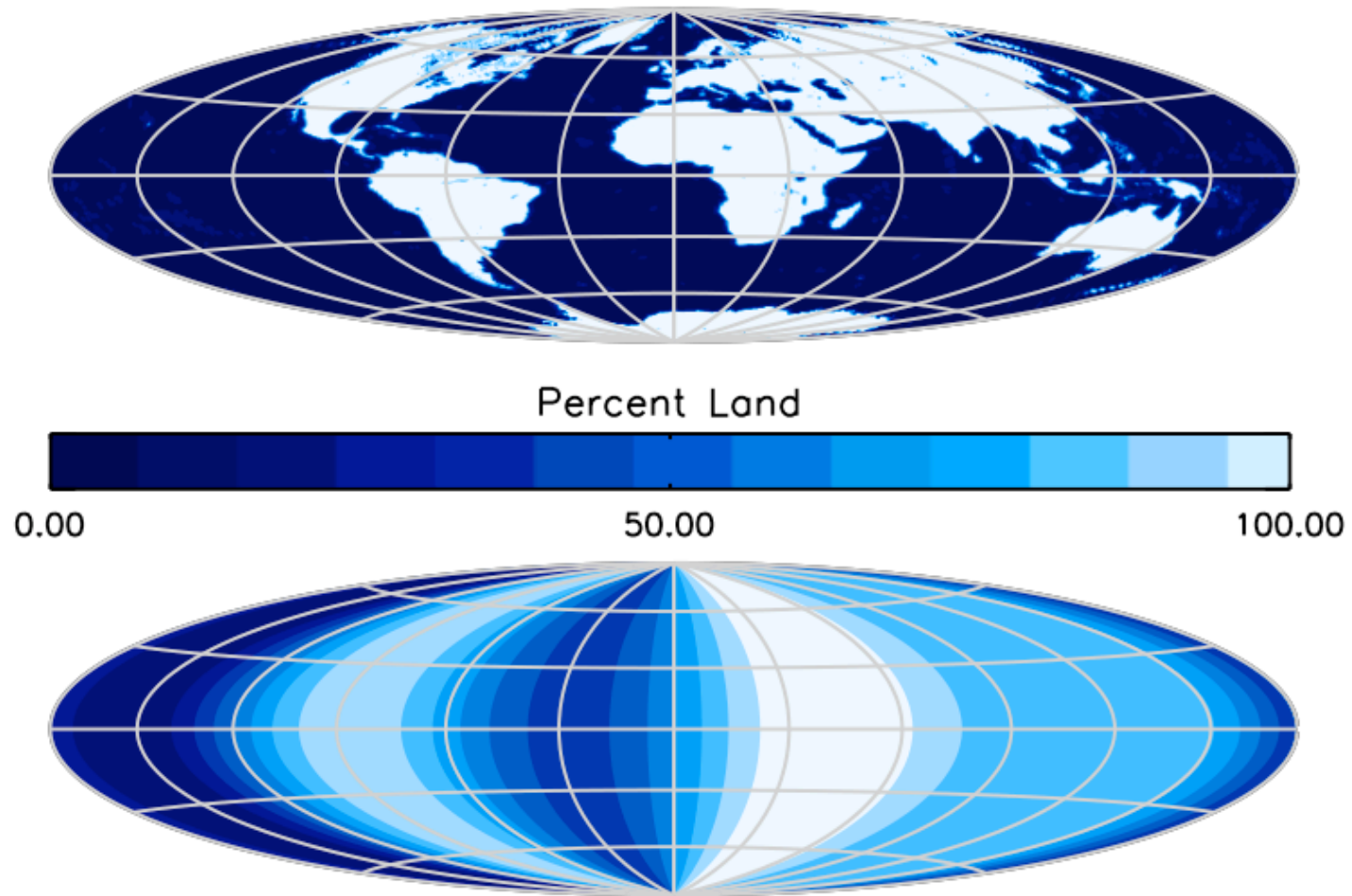


Diffuse (Lambert) Reflection



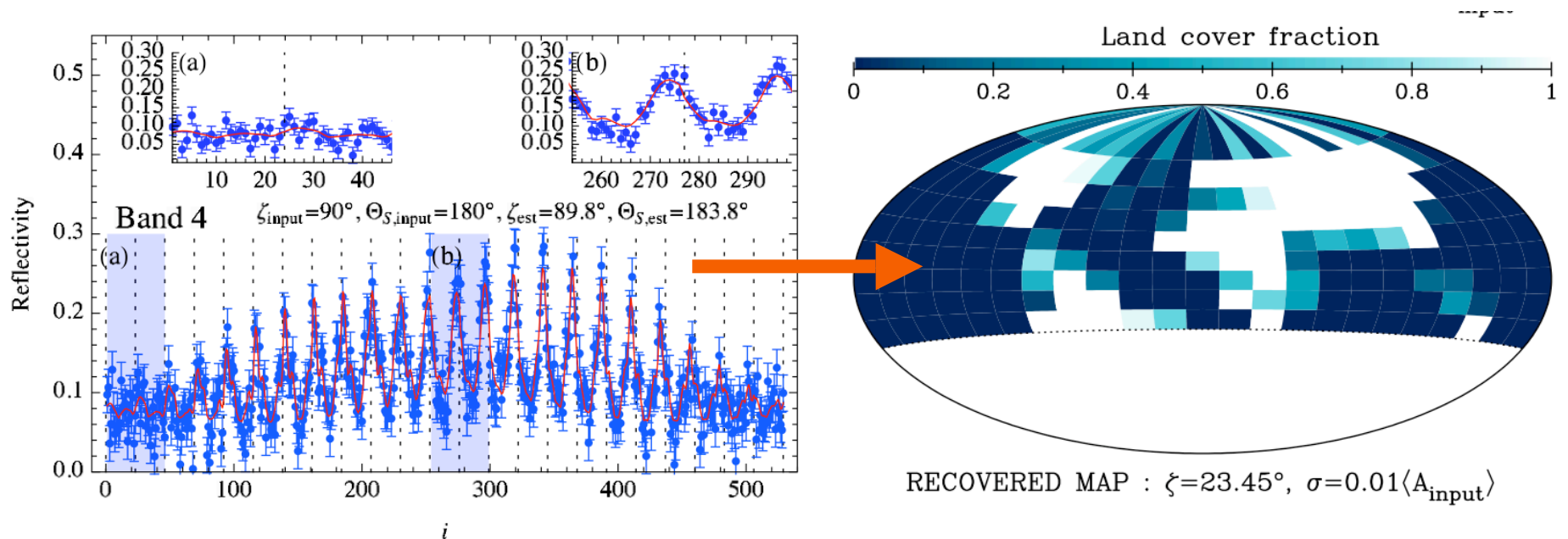
Specular (Shiny) Reflection

Longitudinal Map



Cowan et al. (2009)

Seasonal Mapping

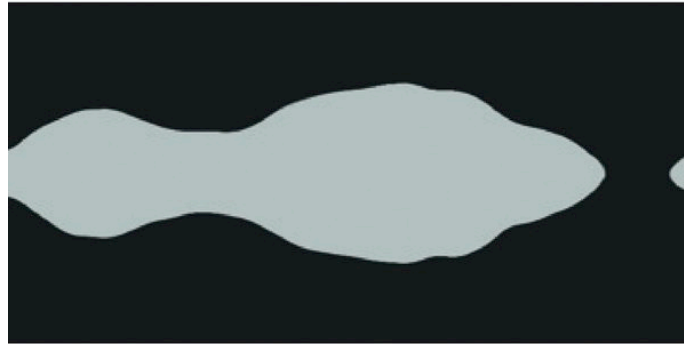


(Fujii et al. 2010, Kawahara & Fujii 2010)

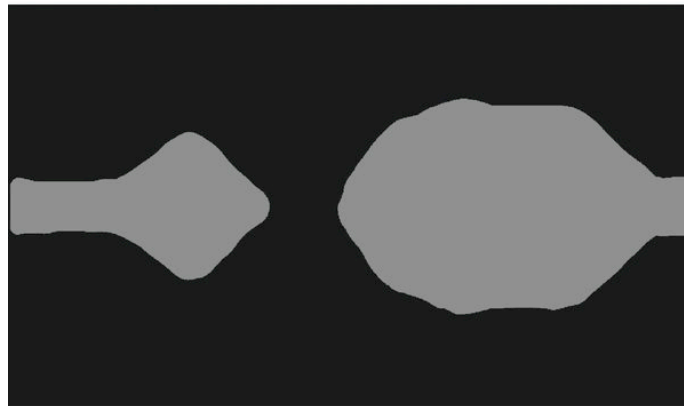
- Seasonal changes in diurnal lightcurve
 - Recover Longitudinal & **Latitudinal** Info
 - Recover **Obliquity** & Solstice

White-Light Map

Real Clouds



25% Real Clouds



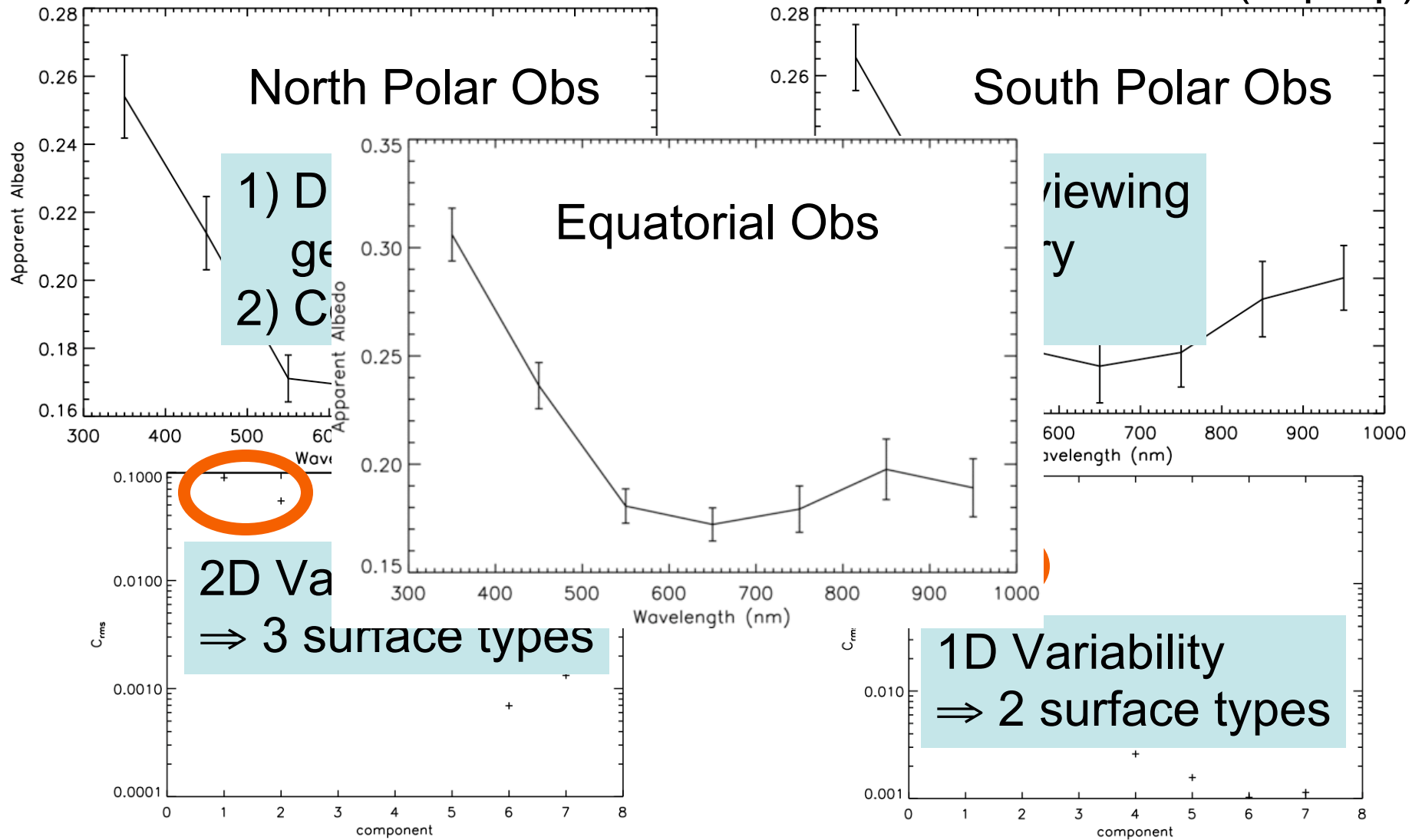
Oakley & Cash (2009)

White-light maps are harder



EPOXI Polar Observations

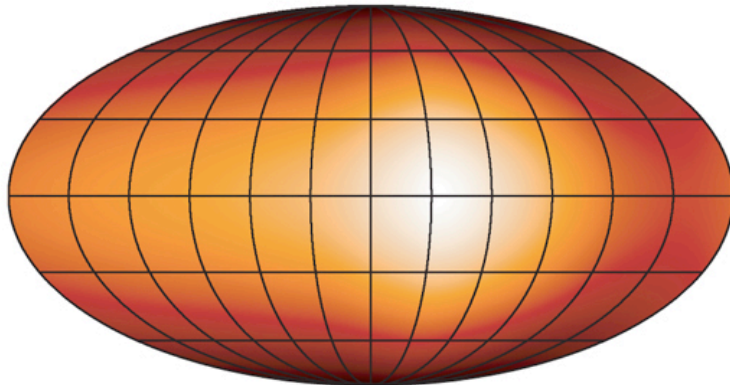
Cowan et al. (in prep)



Summary

Climate Mapping

- 1) Phase Mapping
- 2) Eclipse Mapping
 - Thermal Photometry
 - All Planets
 - ✓ Diurnal Temperature Pattern
 - ✓ Albedo, thermal inertia, winds/rotation



Surface Mapping

- 1) Rotational Mapping
- 2) Seasonal Mapping
 - Reflected Photometry
 - Rocky Planets
 - ✓ Surface Types and Spatial Distributions
 - ✓ Oceans, obliquity, solstice

