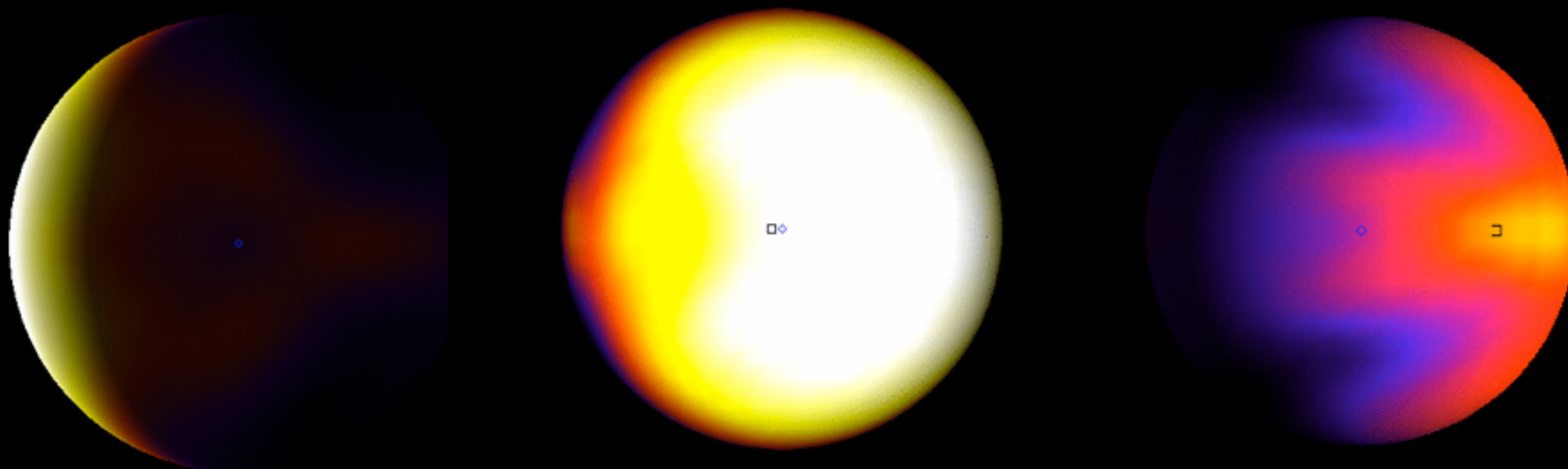
Atmospheric Circulation of Eccentric Hot Jupiter HAT-P-2b



Nikole K. Lewis et al.*

Extreme Solar Systems II

*H. Knutson, A. P. Showman, J. J. Fortney, E. Agol, A. Burrows, D. Charbonneau, N. B. Cowan, D. Deming, J.-M. Desert, J. Langton, G. Laughlin, K. J. Mighell

HAT-P-2b: Eccentric Hot Jupiter

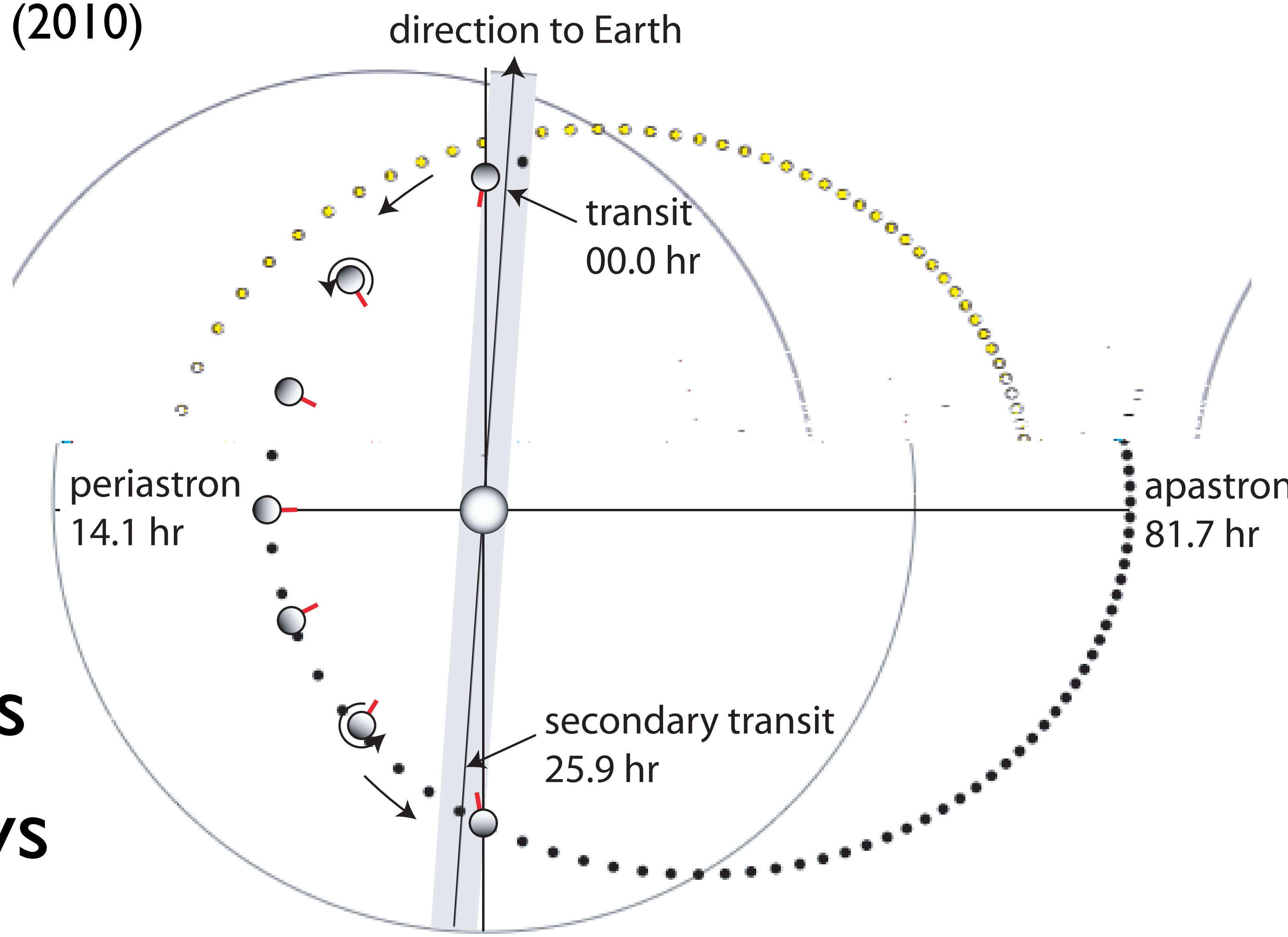
Planetary Parameters*

*Pál et al. (2010)

- $M_P = 9.09\ M_J$
- $R_P = 1.157\ R_J$
- a = 0.06878 AU
- e = 0.5171
- $g_P = 16827\ cm/s^2$
- P_{orb} = 5.6334729 days
- P_{rot}✠ = 1.8927016 days

Stellar Parameters*

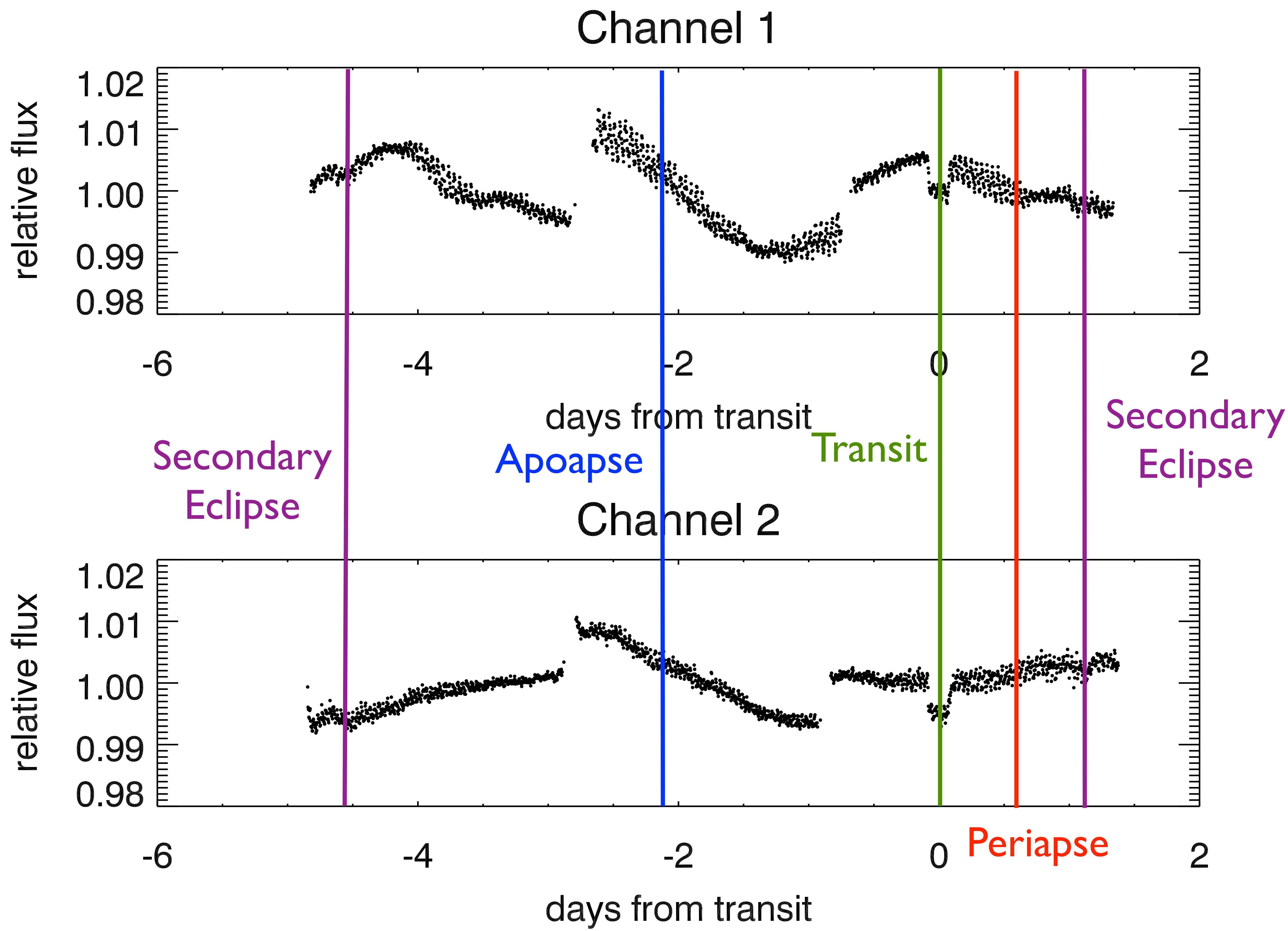
- F8 (T_{eff} ~ 6290 K)



$F_{periastron} = 10 \times F_{apastron}$

✠ Parameterization from Hut (1981)

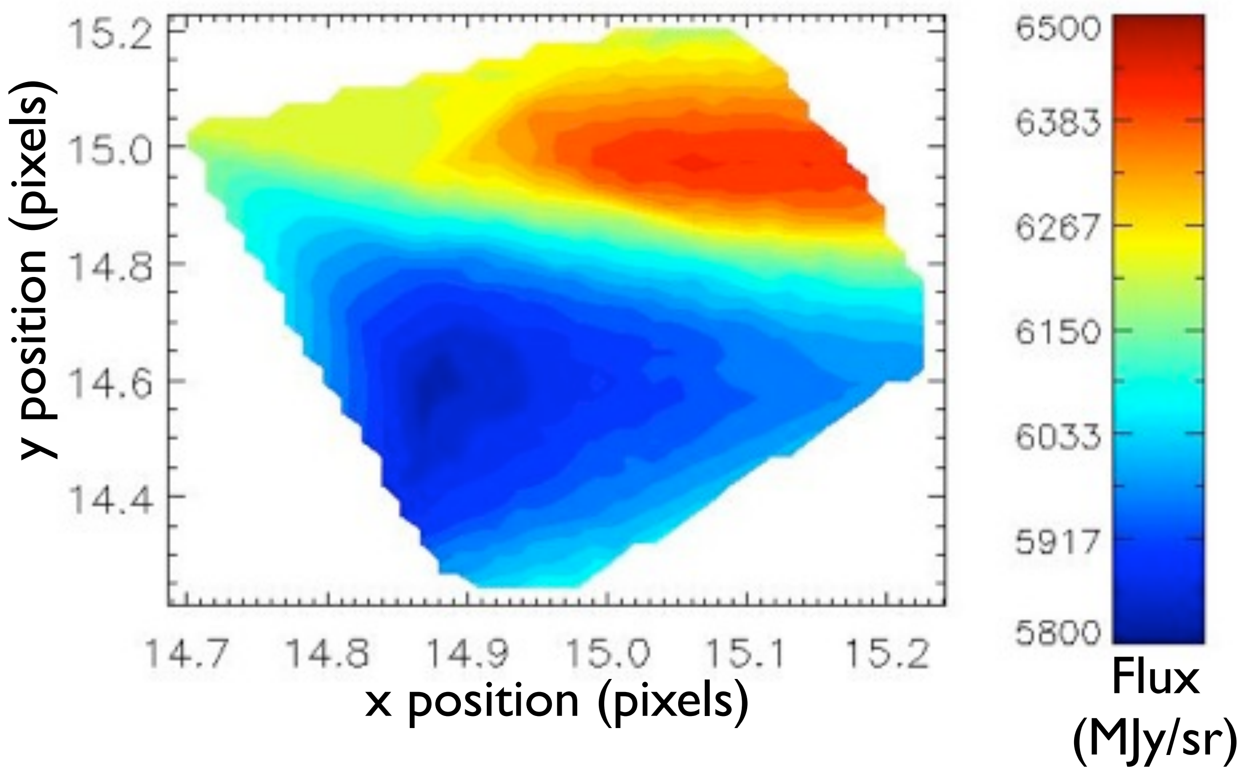
figure credit G. Laughlin (oklo.org)



Over135 hours (1215000+ subarray frames) in each channel

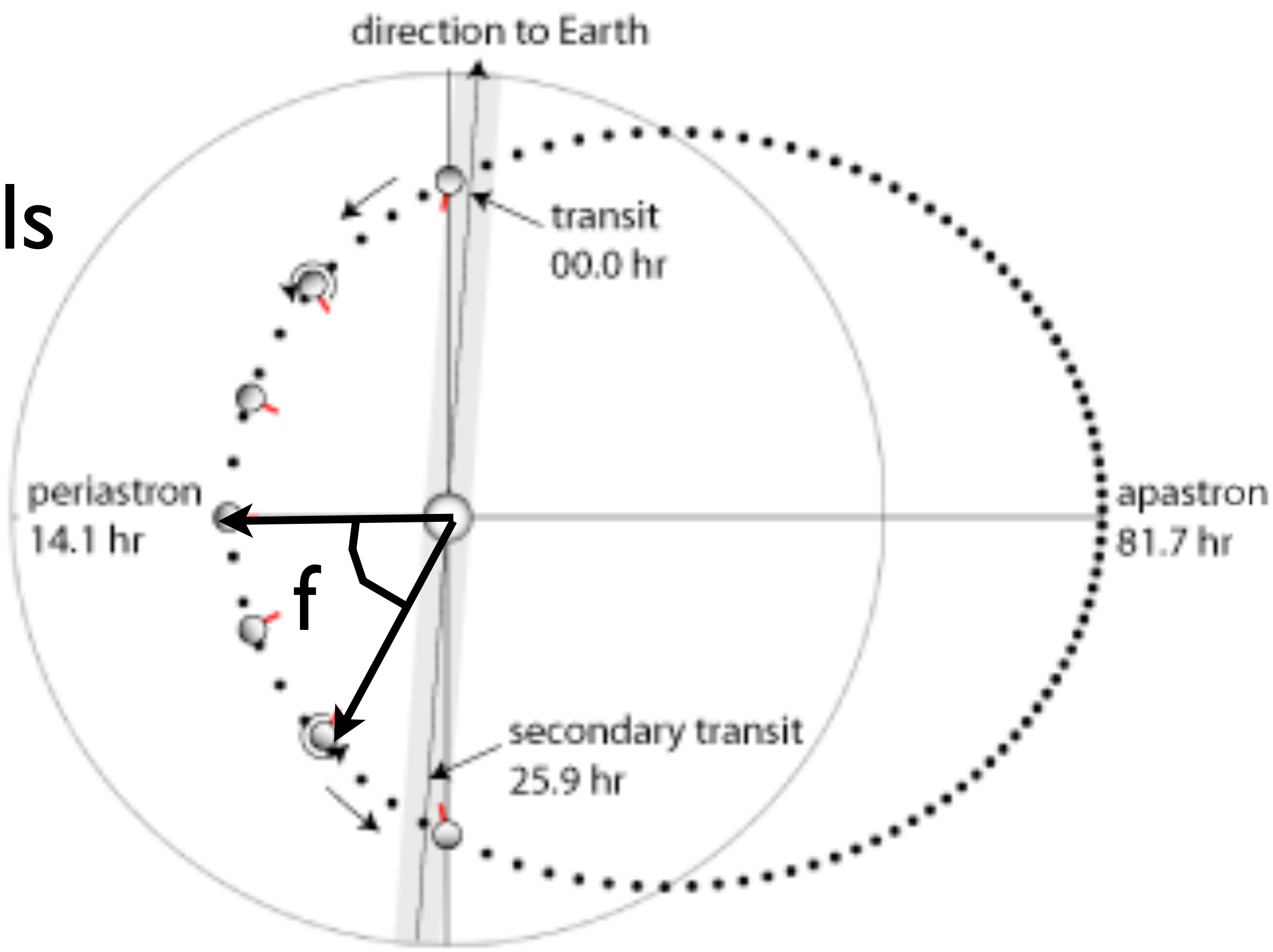
Data Reduction

- Intrapixel sensitivity variations
  ➡Utilize low-pass gaussian filter (ala Ballard et al. (2010))

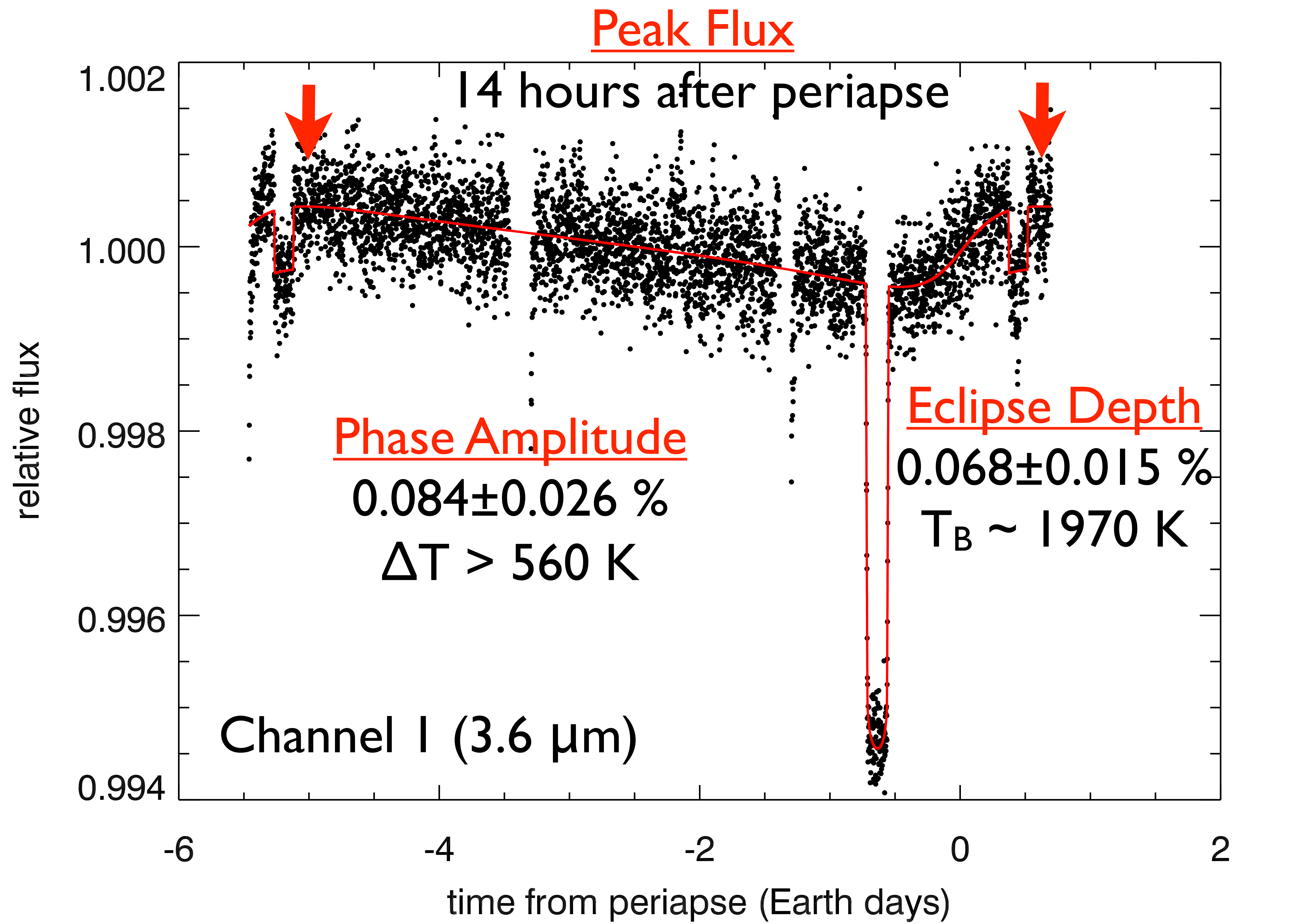


- Flux 'ramp' at start of observations
  ➡Weak in channels 1 and 2 (discard first 10 minutes of data)

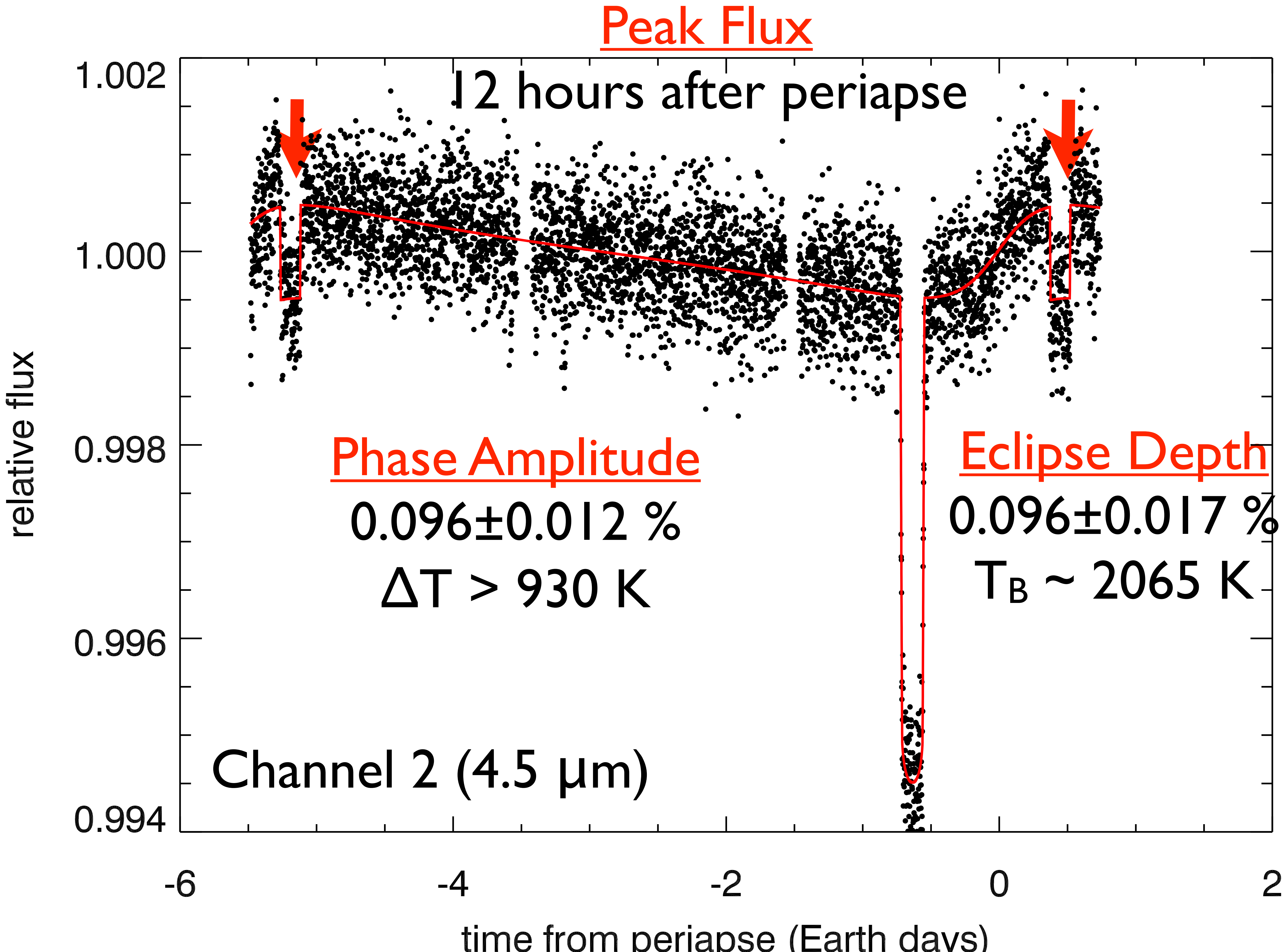
- Transit and eclipse events
  ➡Simultaneous fit of both channels using routines of Mandel & Agol (2002)
  ➡Limb darkening (Sing (2010))



- Phase variations
  ➡ $F \sim A \cos(f + \Phi)$



Peak Flux
14 hours after periapse
Phase Amplitude
0.084±0.026 %
ΔT > 560 K
Eclipse Depth
0.068±0.015 %
T_B ~ 1970 K
Channel 1 (3.6 μm)
1.002
1.000
0.998
0.996
0.994
relative flux
-6
-4
-2
0
2
time from periapse (Earth days)



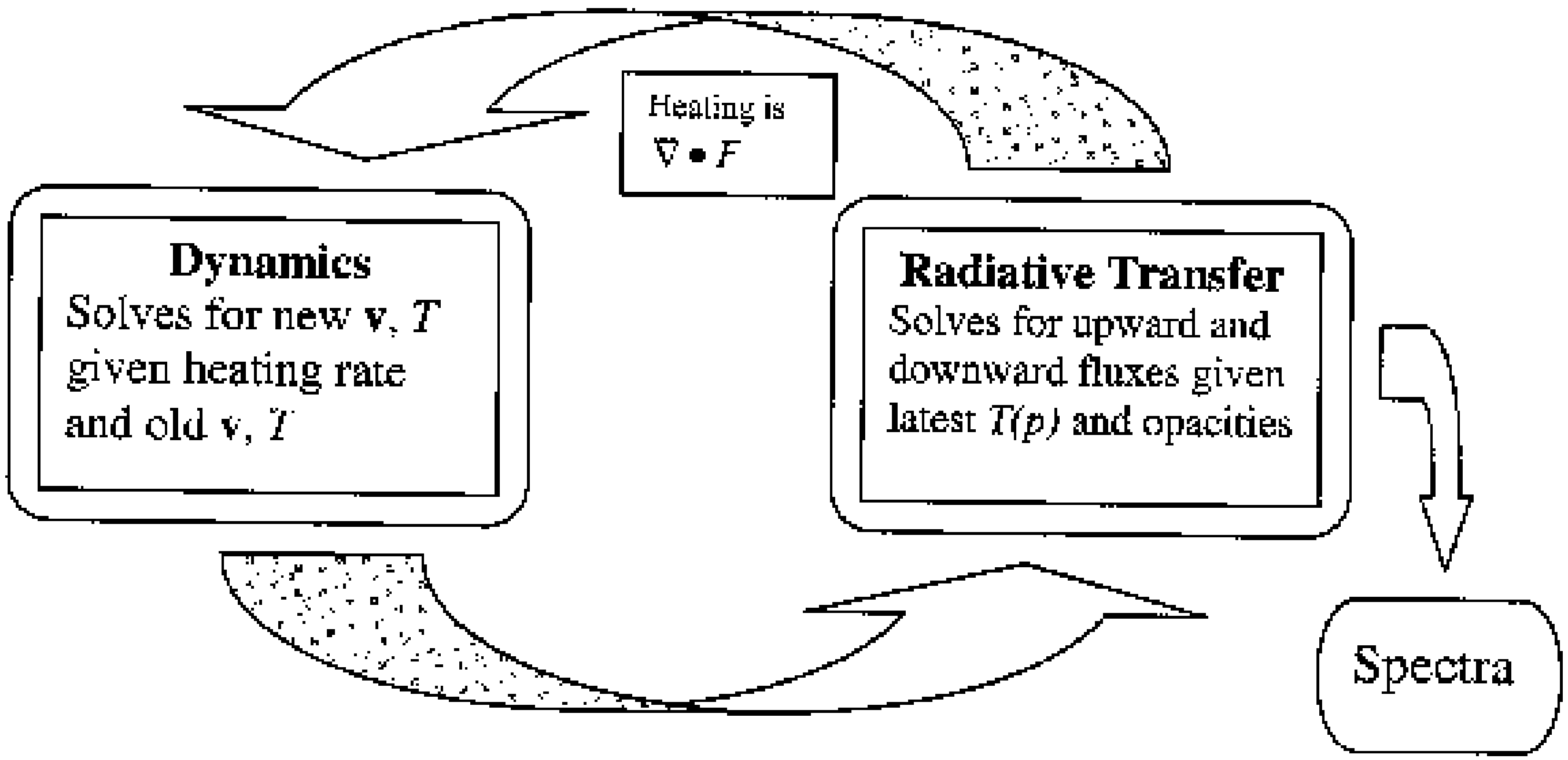
Peak Flux
12 hours after periapse
Phase Amplitude
0.096±0.012 %
ΔT > 930 K
Eclipse Depth
0.096±0.017 %
T_B ~ 2065 K
Channel 2 (4.5 µm)
relative flux
1.002
1.000
0.998
0.996
0.994
-6
-4
-2
0
2
time from periapse (Earth days)

SPARC Model Atmosphere

(Substellar and Planetary Atmospheric Radiation and Circulation Model)

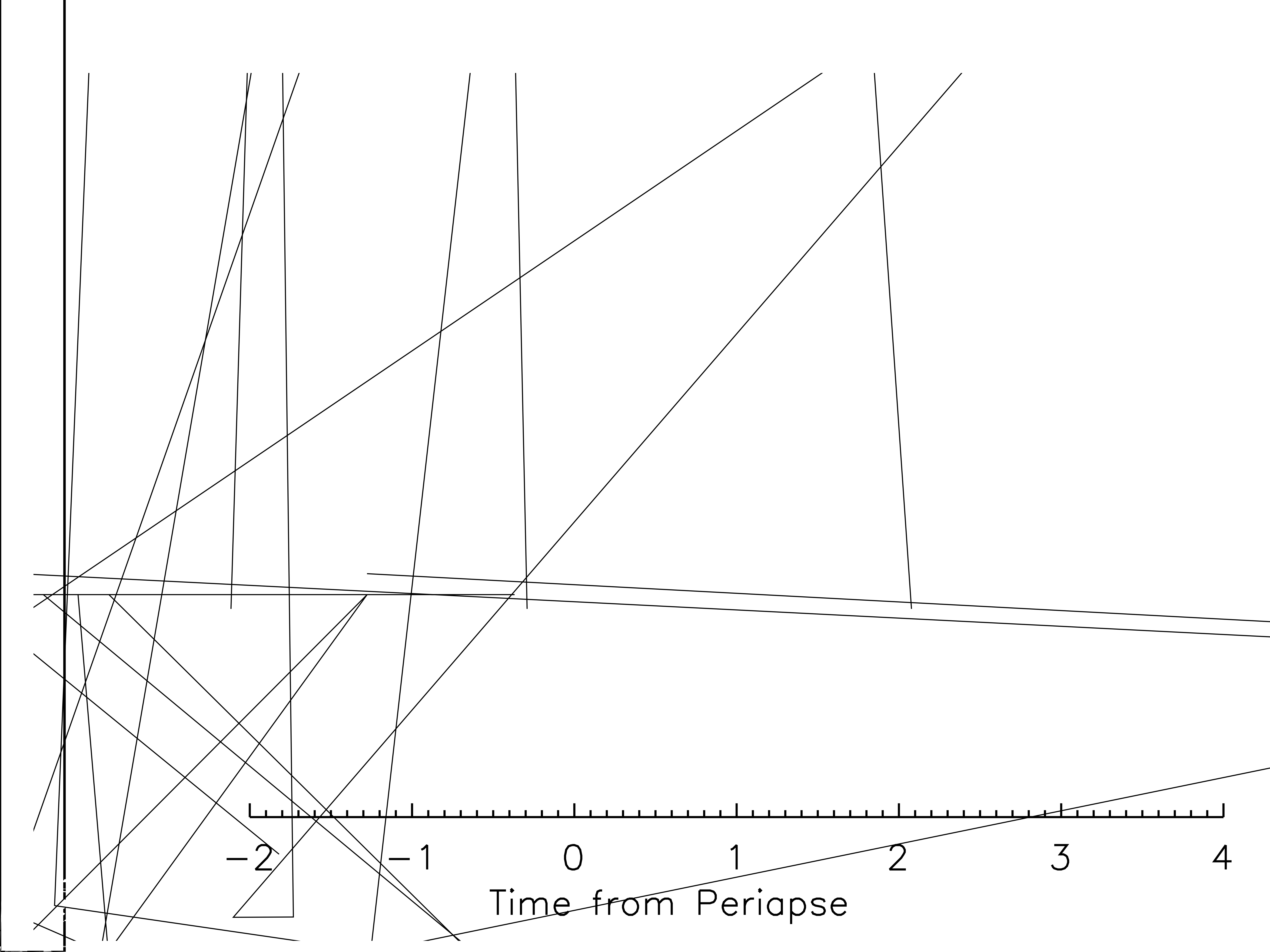
Dynamics

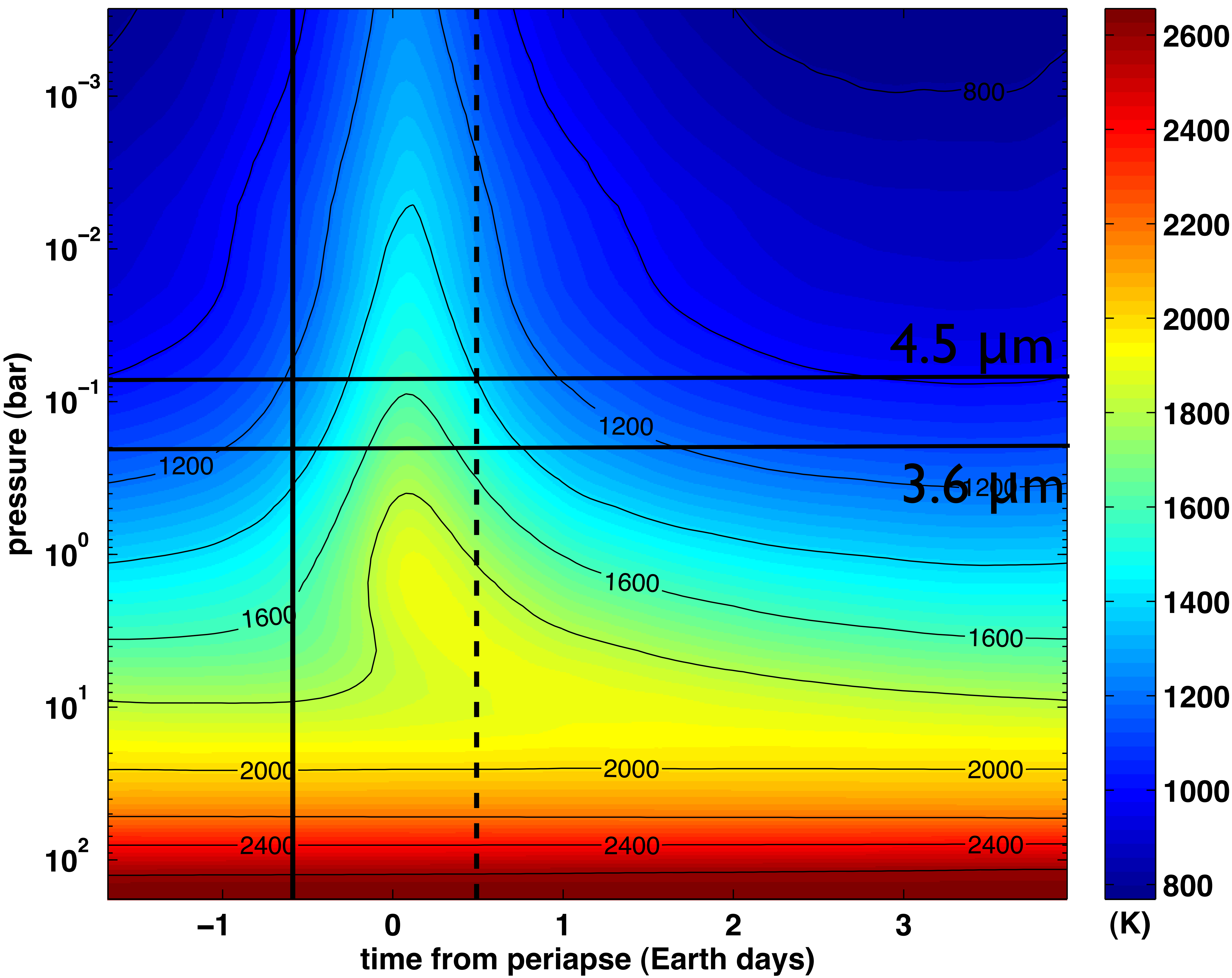
- MIT General Circulation Model (MITgcm)
- Solves 3D primitive equations



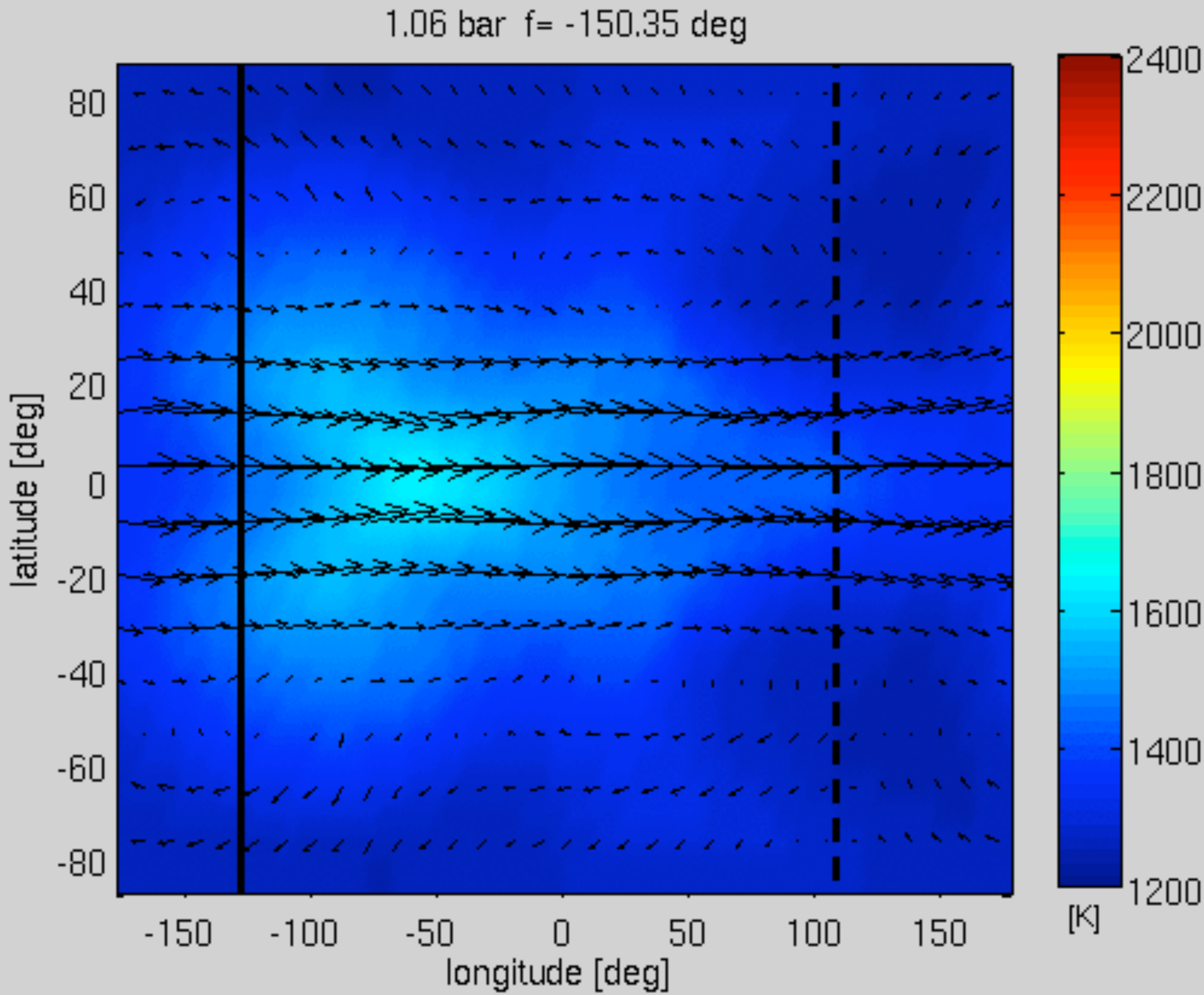
Radiative Transfer

- Based on Marley & McKay (1999) radiative transfer model
- Plane-parallel two-stream non-gray radiative transfer scheme
- Opacities calculated assuming local thermochemical equilibrium

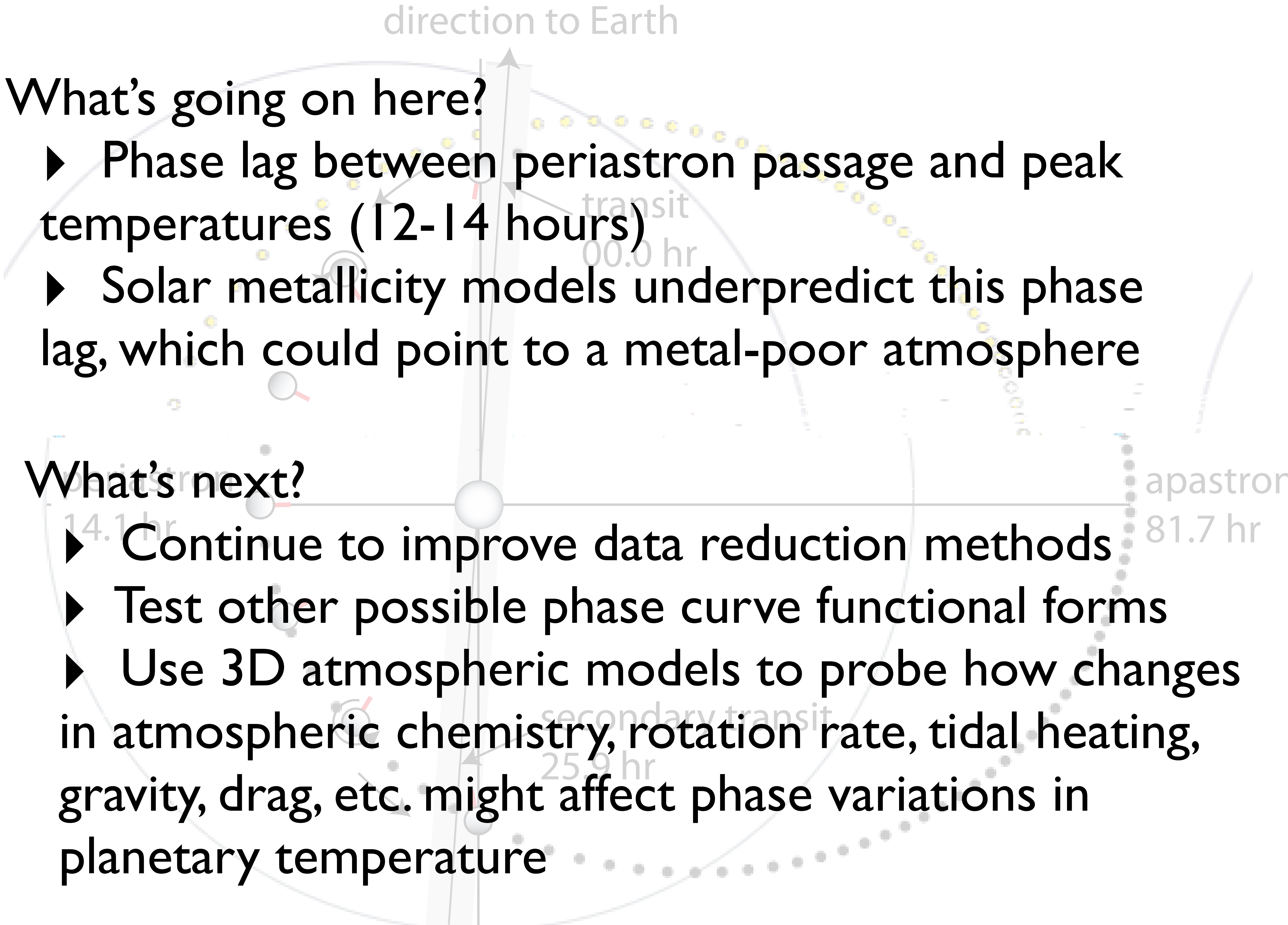

−2
−1
0
1
2
3
4
Time from Periapse



4.5 μm
3.6 μm
800
1200
1200
1200
1600
1600
1600
2000
2000
2000
2400
2400
2400
pressure (bar)
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
−1
0
1
2
3
time from periapse (Earth days)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
(K)



1.06 bar f= -150.35 deg
80
60
40
20
0
-20
-40
-60
-80
latitude [deg]
-150
-100
-50
0
50
100
150
longitude [deg]
2400
2200
2000
1800
1600
1400
1200
[K]

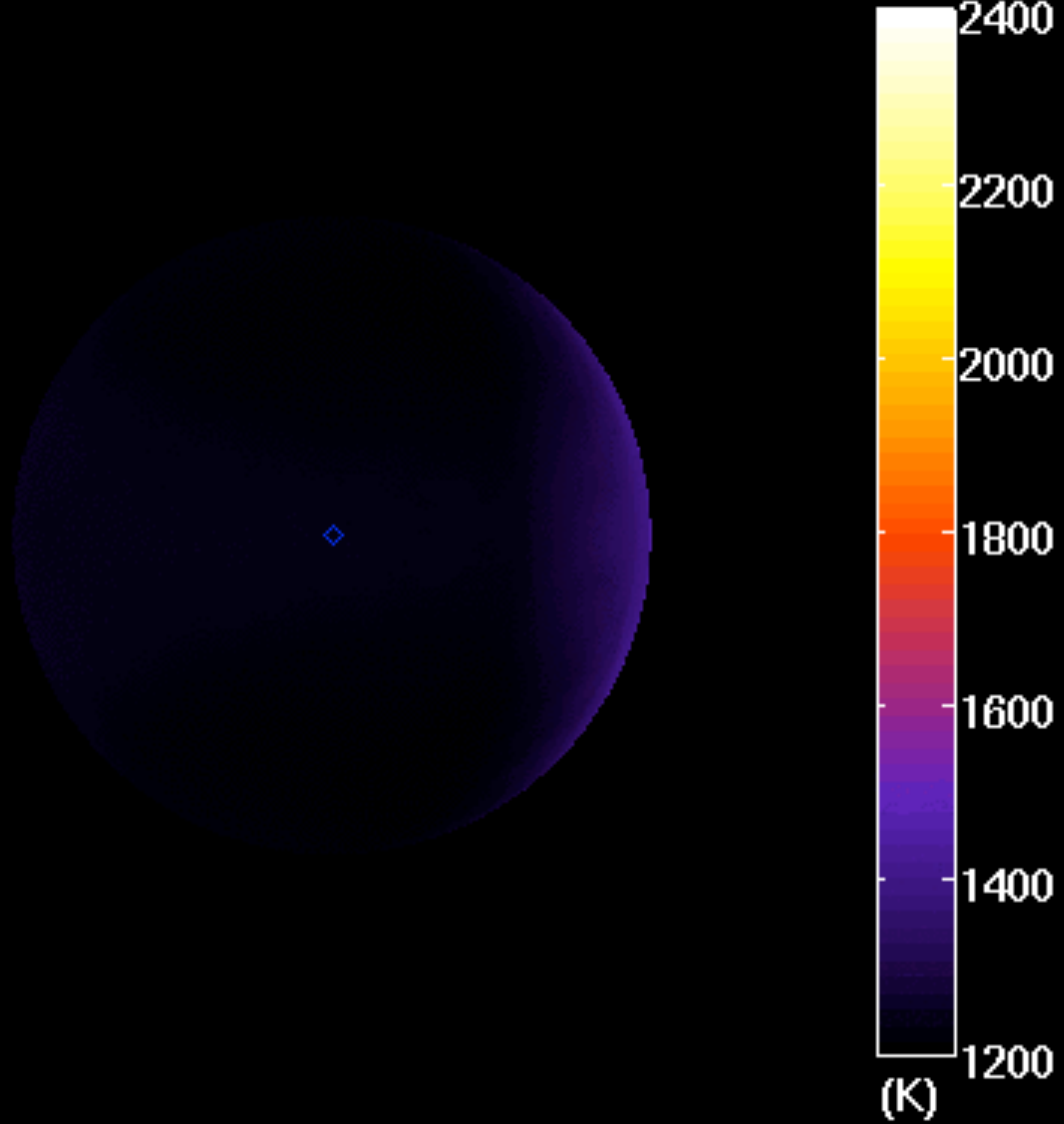


What's going on here?

- Phase lag between periastron passage and peak temperatures (12-14 hours)
- Solar metallicity models underpredict this phase lag, which could point to a metal-poor atmosphere

What's next?

- Continue to improve data reduction methods
- Test other possible phase curve functional forms
- Use 3D atmospheric models to probe how changes in atmospheric chemistry, rotation rate, tidal heating, gravity, drag, etc. might affect phase variations in planetary temperature


2400
2200
2000
1800
1600
1400
1200
(K)