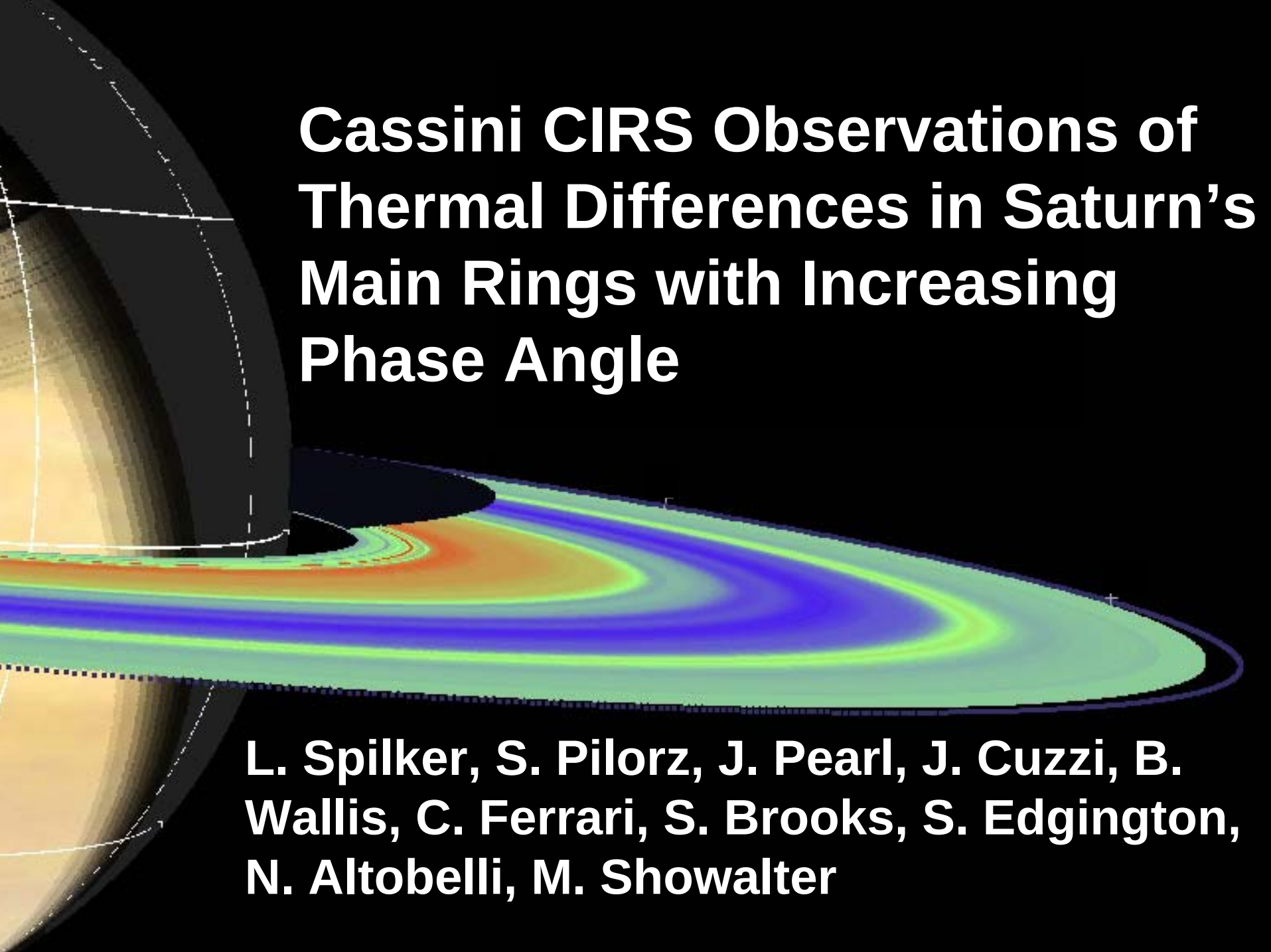
Cassini CIRS Observations of Thermal Differences in Saturn's Main Rings with Increasing Phase Angle



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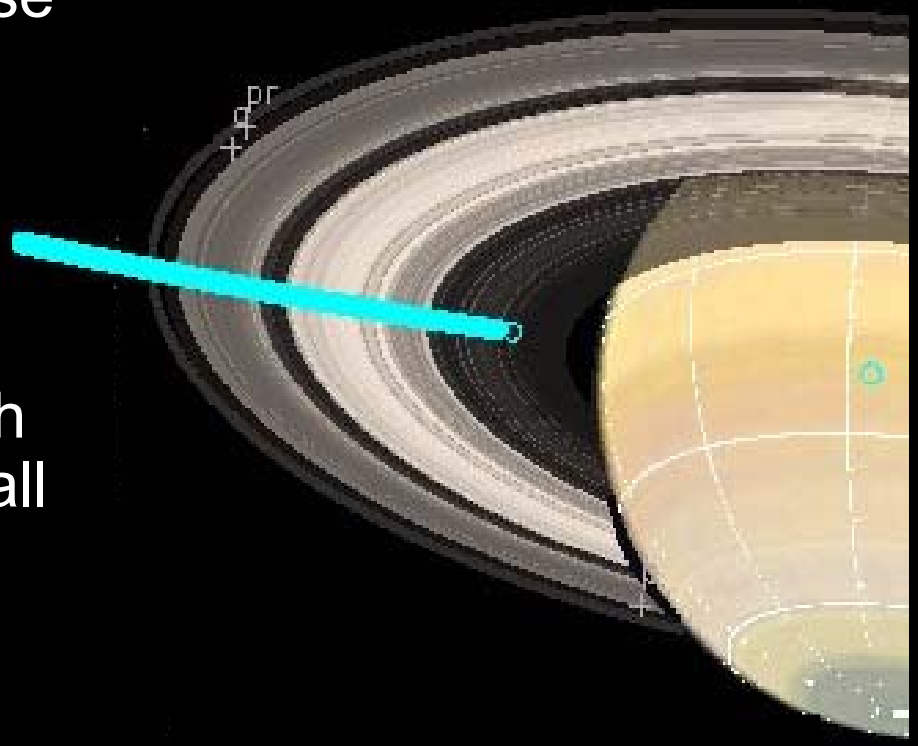
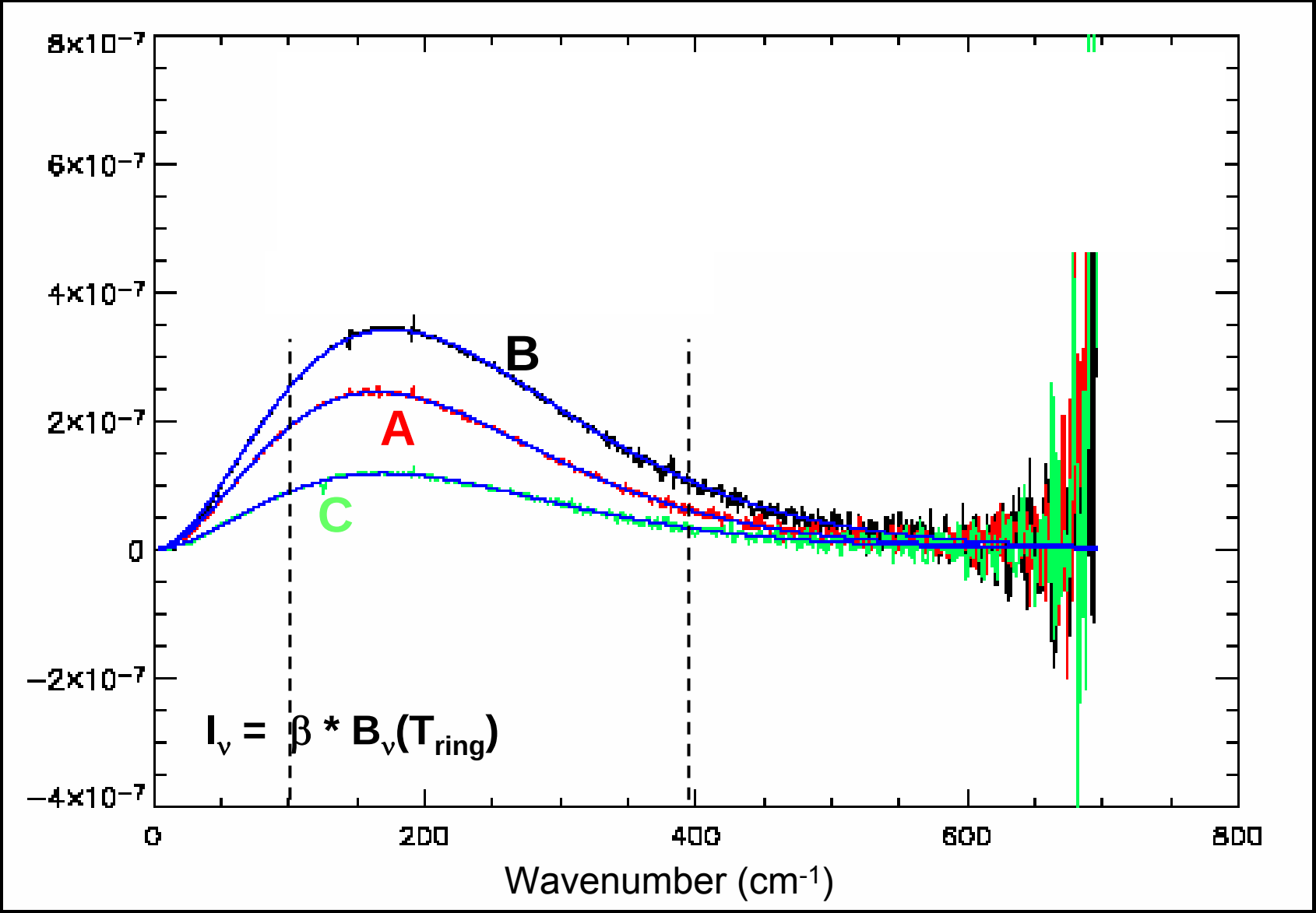
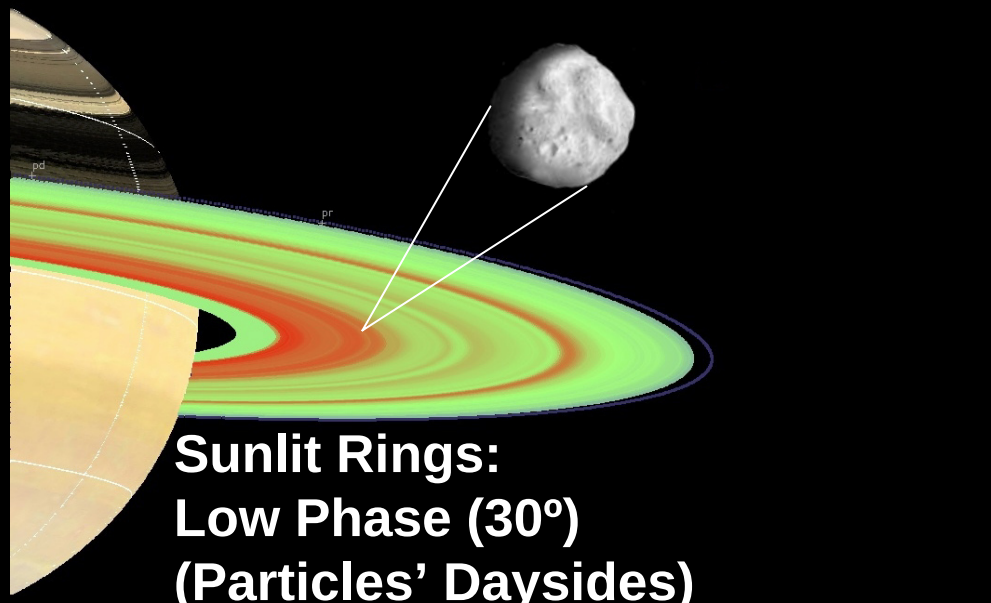
Introduction

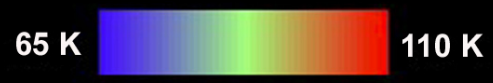
- Radial scans of main rings obtained at a variety of phase angles, local times and ring opening angles
  - Circular focal plane 1 slowly scanned across rings
  - Radial resolution ~2500 km
- Temperatures decrease with increasing phase angle for all main rings

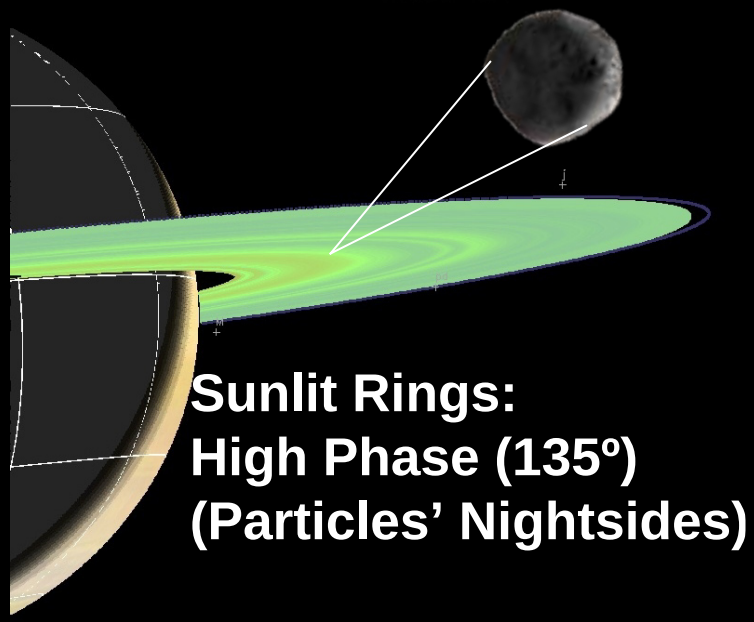


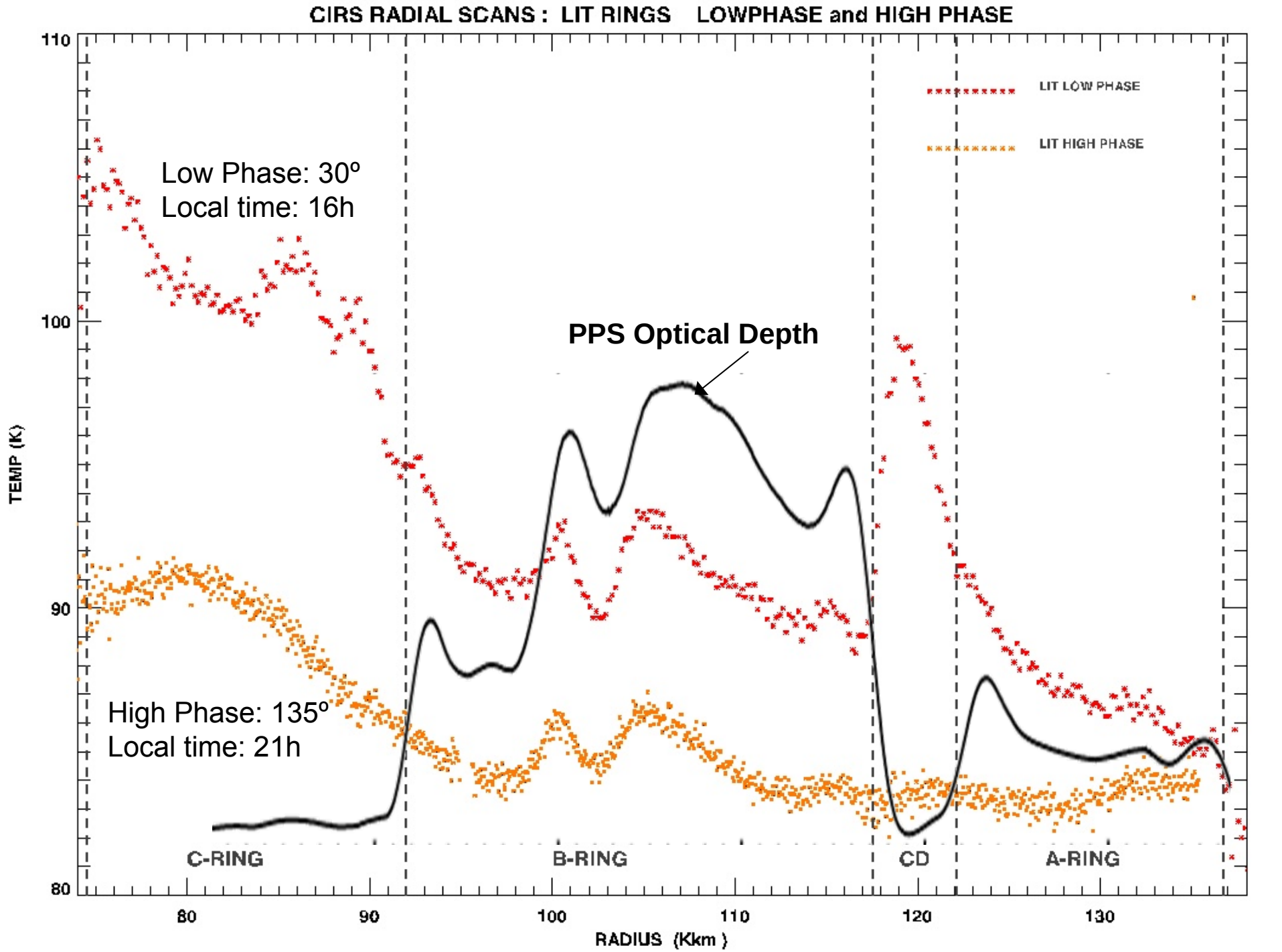
Planck Fits to CIRS Spectra

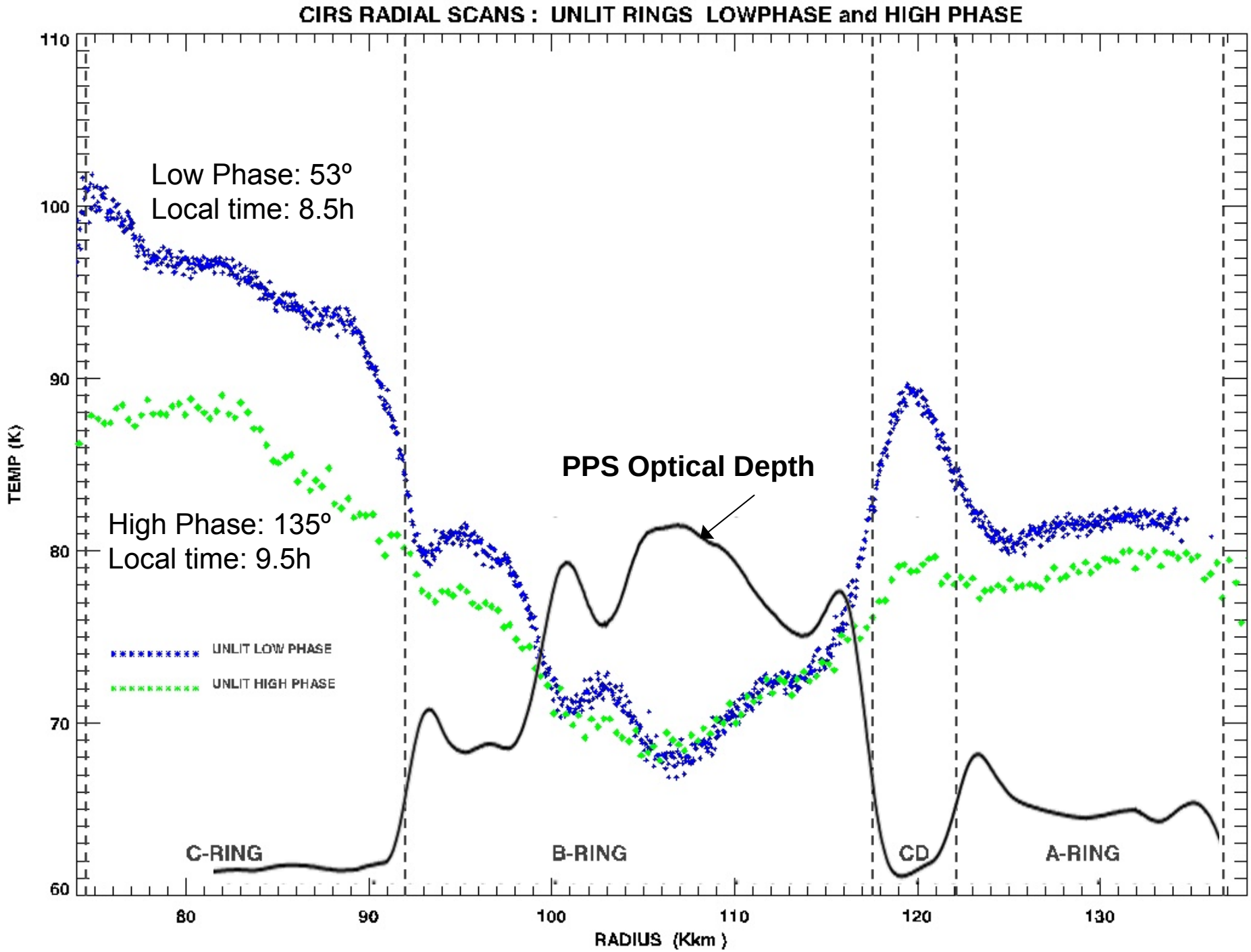


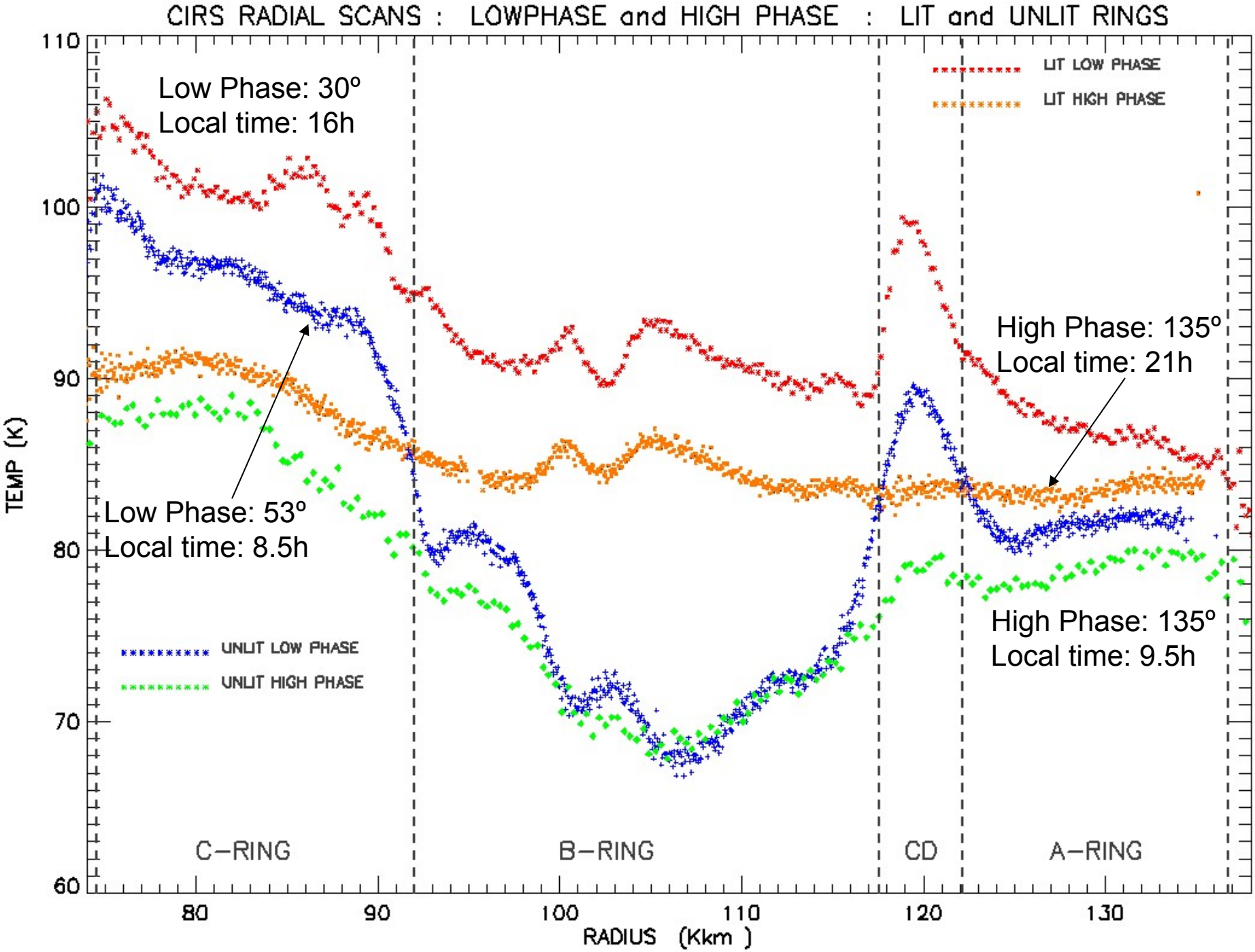

Sunlit Rings:
Low Phase (30º)
(Particles' Daysides)


65 K
110 K


Sunlit Rings:
High Phase (135º)
(Particles' Nightsides)


CIRS RADIAL SCANS : LIT RINGS LOWPHASE and HIGH PHASE
LIT LOW PHASE
LIT HIGH PHASE
Low Phase: 30º
Local time: 16h
PPS Optical Depth
High Phase: 135º
Local time: 21h
C-RING
B-RING
CD
A-RING
TEMP (K)
RADIUS (Kkm)
110
100
90
80
80
90
100
110
120
130

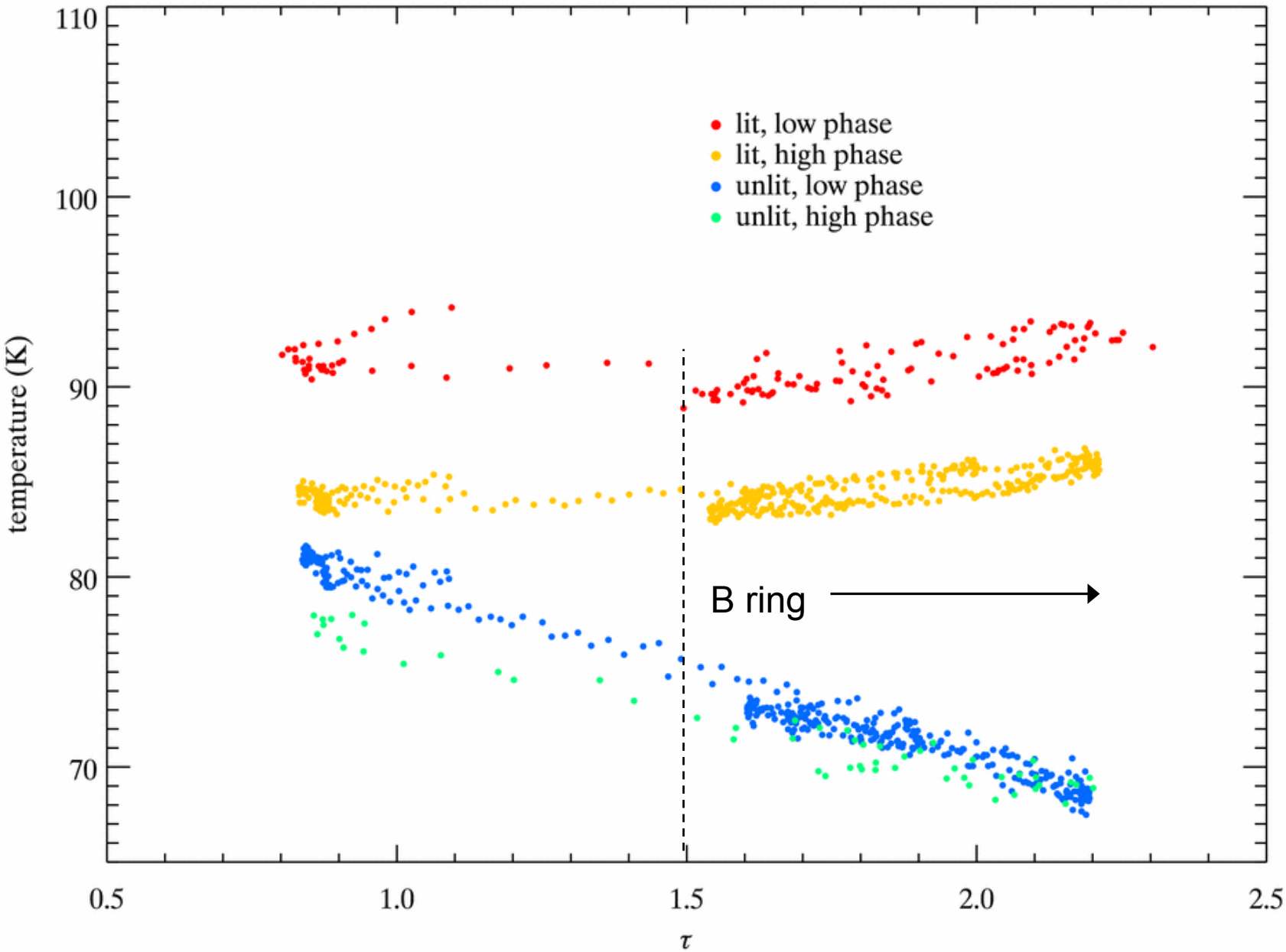

CIRS RADIAL SCANS : UNLIT RINGS LOWPHASE and HIGH PHASE
Low Phase: 53º
Local time: 8.5h
High Phase: 135º
Local time: 9.5h
PPS Optical Depth
UNLIT LOW PHASE
UNLIT HIGH PHASE
C-RING
B-RING
CD
A-RING
TEMP (K)
RADIUS (Kkm)
110
100
90
80
70
60
80
90
100
110
120
130


CIRS RADIAL SCANS : LOWPHASE and HIGH PHASE : LIT and UNLIT RINGS
LIT LOW PHASE
LIT HIGH PHASE
Low Phase: 30º
Local time: 16h
High Phase: 135º
Local time: 21h
Low Phase: 53º
Local time: 8.5h
High Phase: 135º
Local time: 9.5h
UNLIT LOW PHASE
UNLIT HIGH PHASE
C–RING
B–RING
CD
A–RING
TEMP (K)
RADIUS (Kkm)
110
100
90
80
70
60
80
90
100
110
120
130

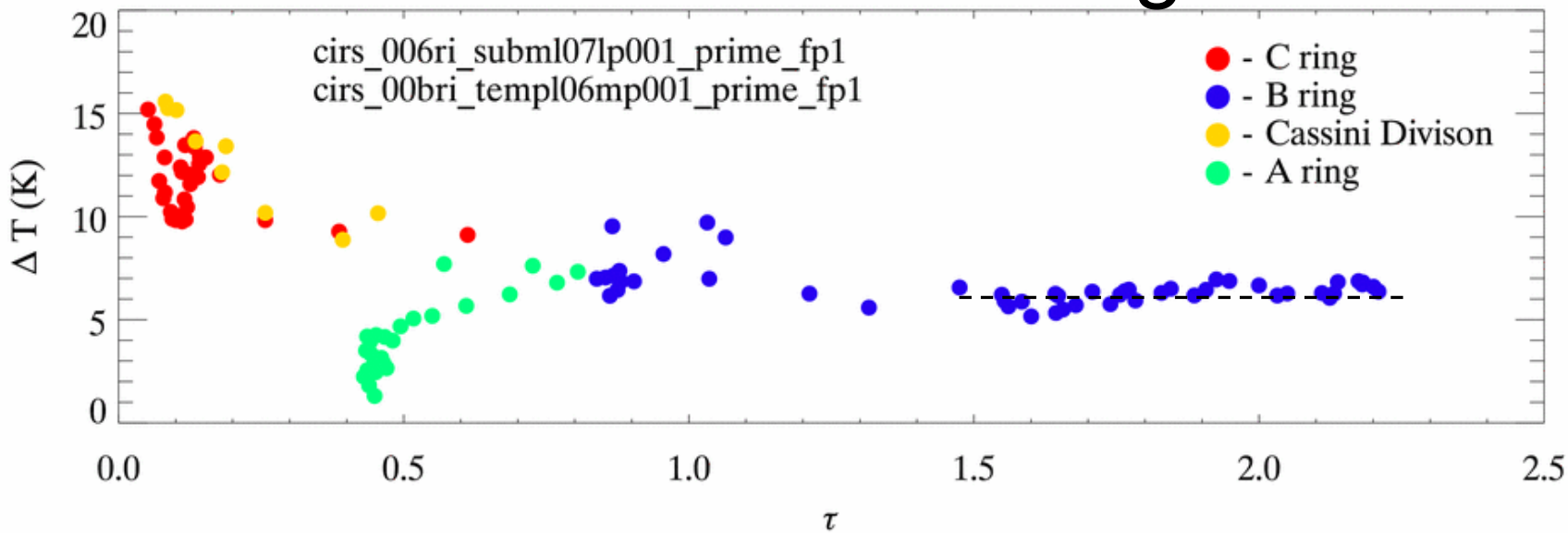
Estimate of Particle Spin Period

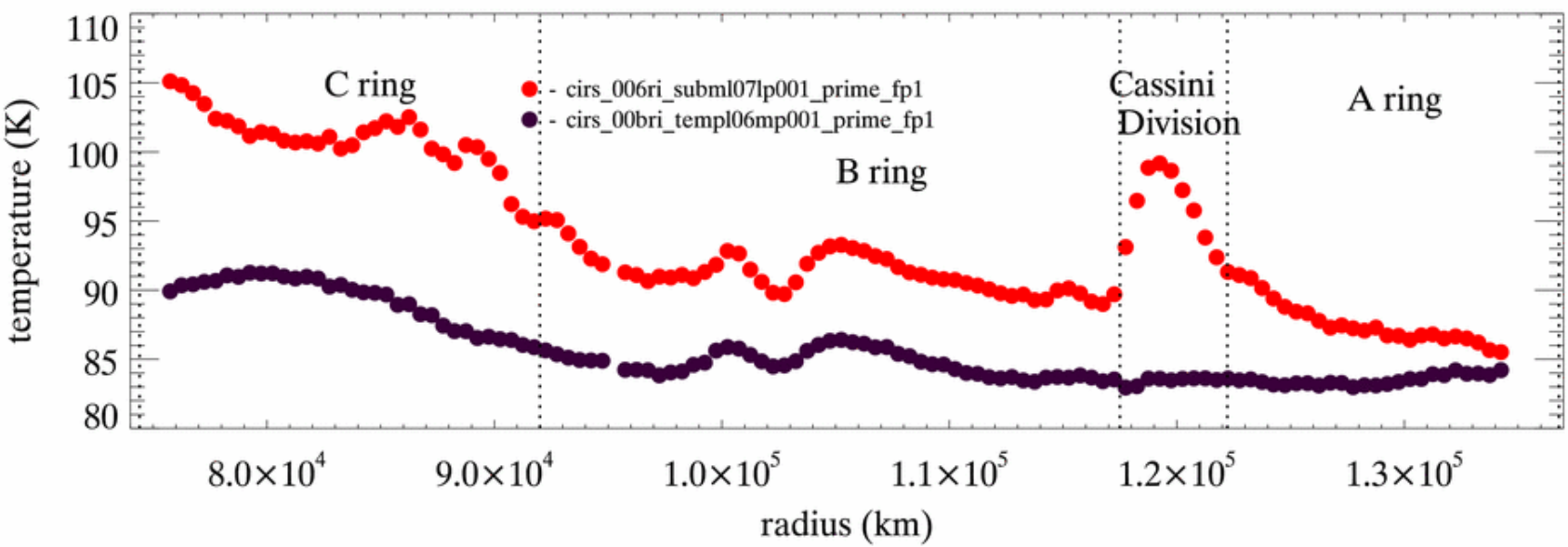
- Assume polar-aligned spin axes, heating from Sun
- Assume each surface element absorbs heat from Sun 1/2 time, emits heat remaining 1/2 time
- Characteristic time for radiating heat
  - $t_{char} = \Delta Q/\sigma T^4_{dark}$ where $t_{char} < P/2$ (to maintain gradient)
    - $\Delta Q \sim \rho C_p \Delta T \, \delta_P = 2\Gamma \Delta T \, (P/(2\pi))^{1/2}$
    - where Γ is thermal inertia, P is spin period,
    - δ_P is skin depth, $\sim 2 \Gamma (P/(2\pi))^{1/2} \rho^{-1} C_p^{-1}$
- Spin Period: $P > (8/\pi)[\Gamma \Delta T/(\sigma T^4_{dark})]^2$
- B ring: $\Gamma = 15$ $JK^{-1}m^{-2}sec^{-1/2}$, $\Delta T = 10K$, $T_{dark} = 85K$
- Then $P > 1.8$ hours, lower limit for spin period

Temperature vs. Optical Depth

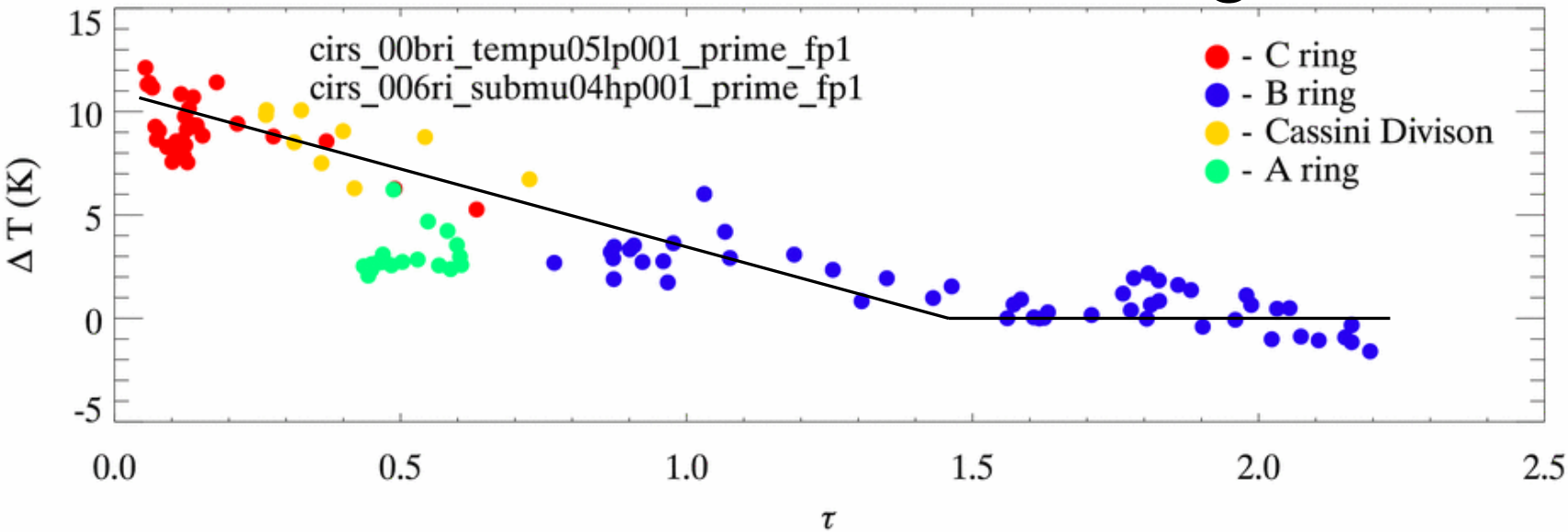


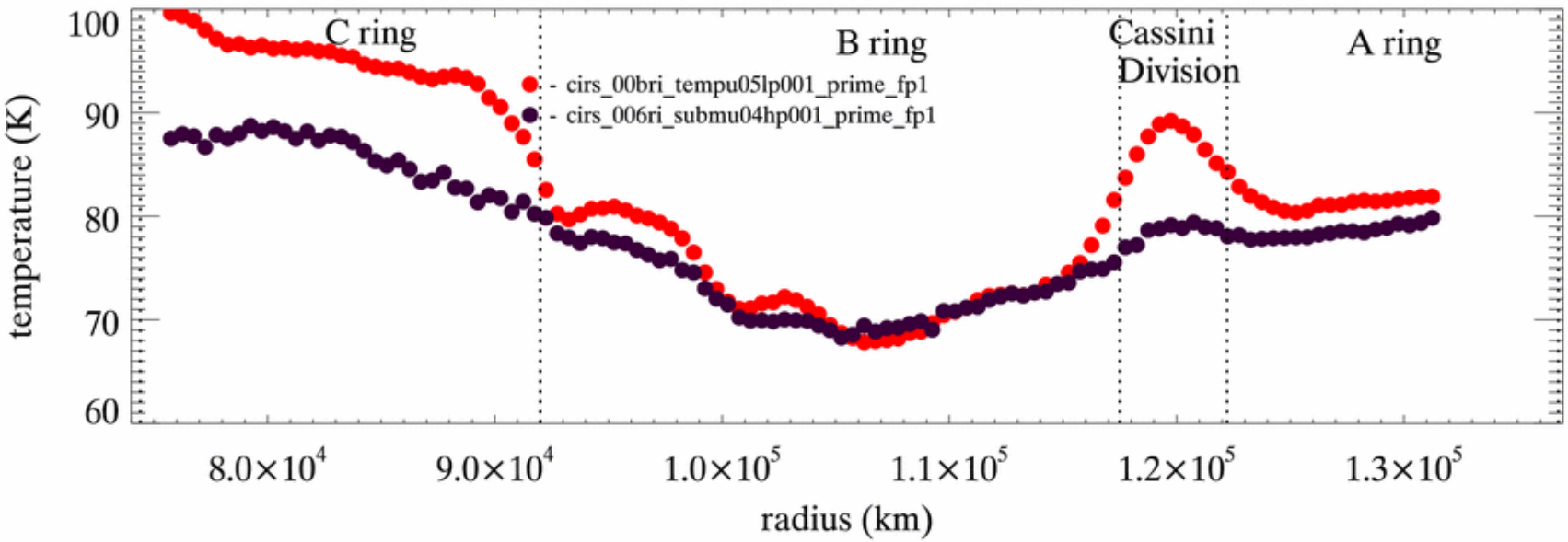
ΔT: Lit Low Phase - Lit High Phase





ΔT: Unlit Low Phase - Unlit High Phase



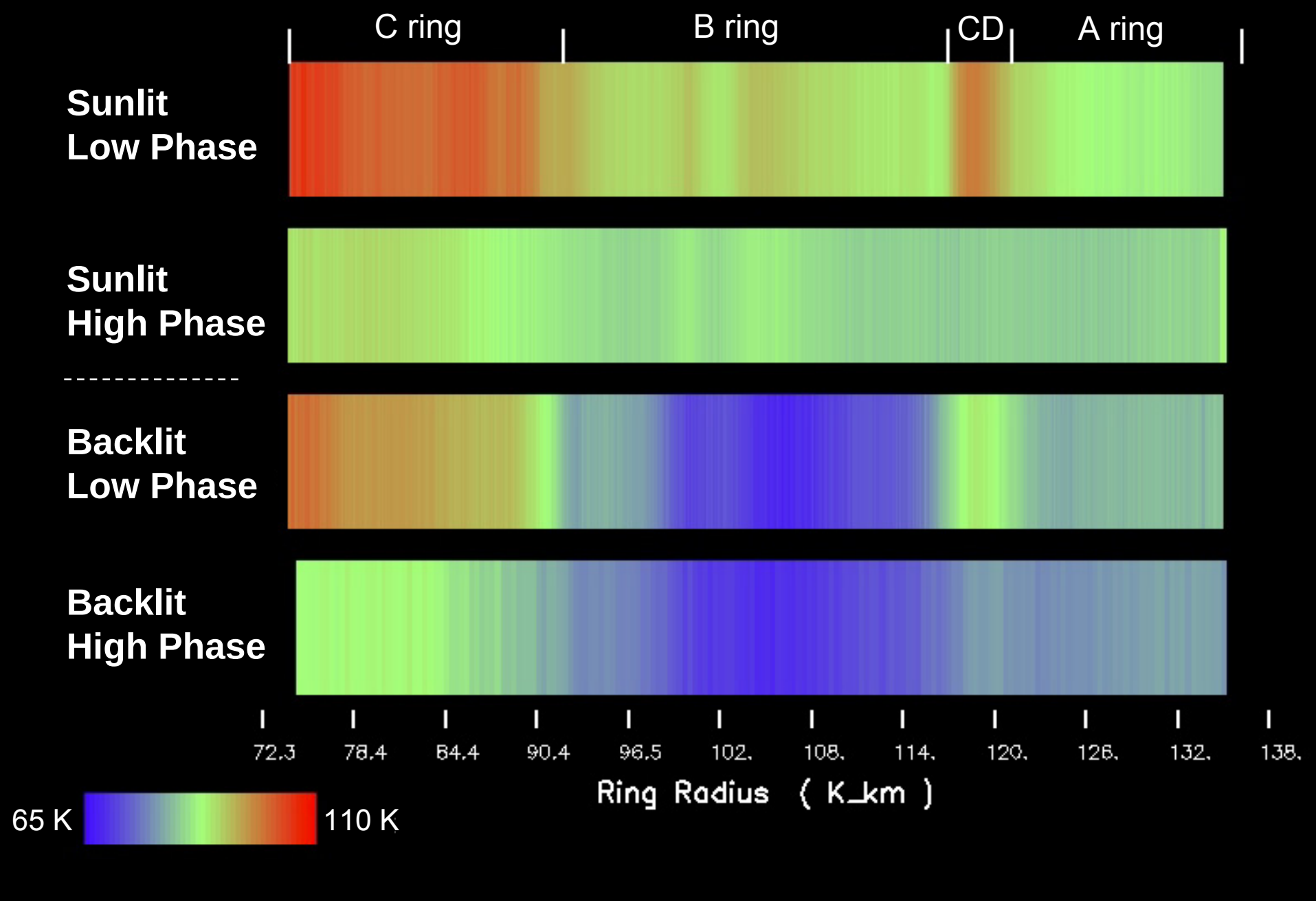


Conclusions

- Temperatures decrease with increasing phase angle in A, B, C and Cassini Division suggesting a population of slowly rotating ring particles
- Rough estimate of particle spin period for B ring particle is $P > 1.8$ hours
- T vs. τ
  - Slightly correlated on lit side, anticorrelated on unlit side (thicker rings block more photons on unlit side)
- ΔT vs. τ
  - C ring and Cassini Division ΔT change rapidly with τ
  - Unlit B ring $\Delta T = 0$ above $\tau = 1.5$ suggesting very little vertical mixing in thickest parts of B ring

END

CIRS Ring Scans

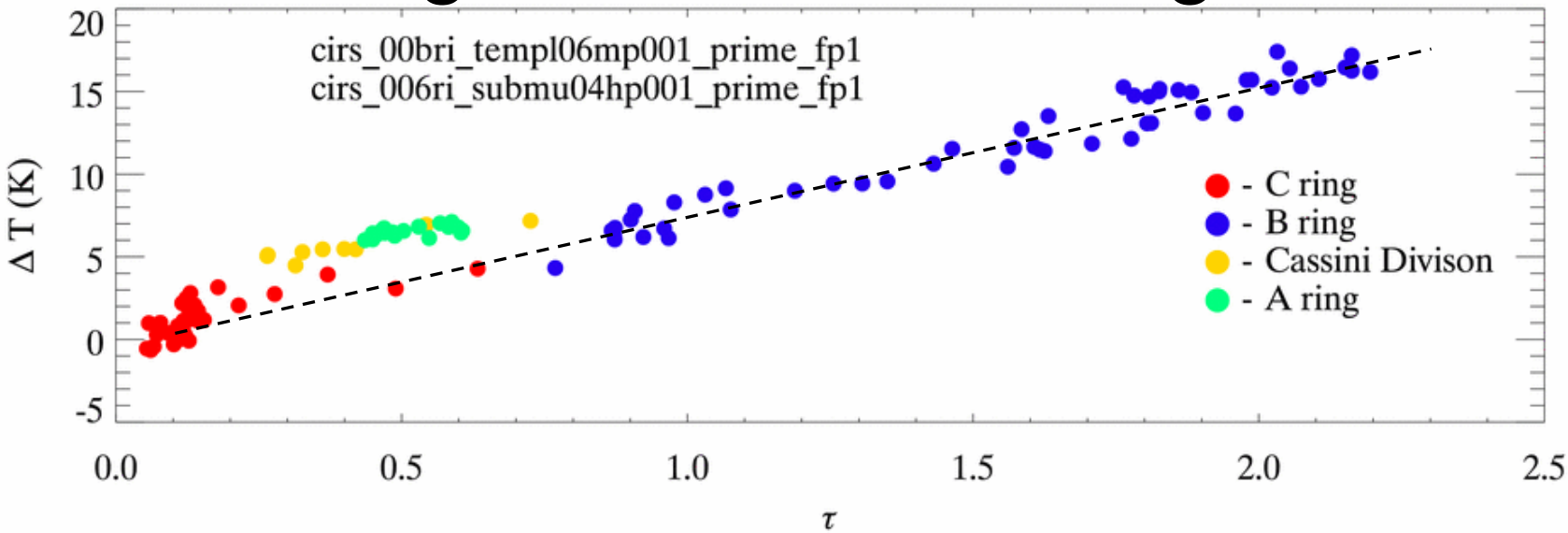


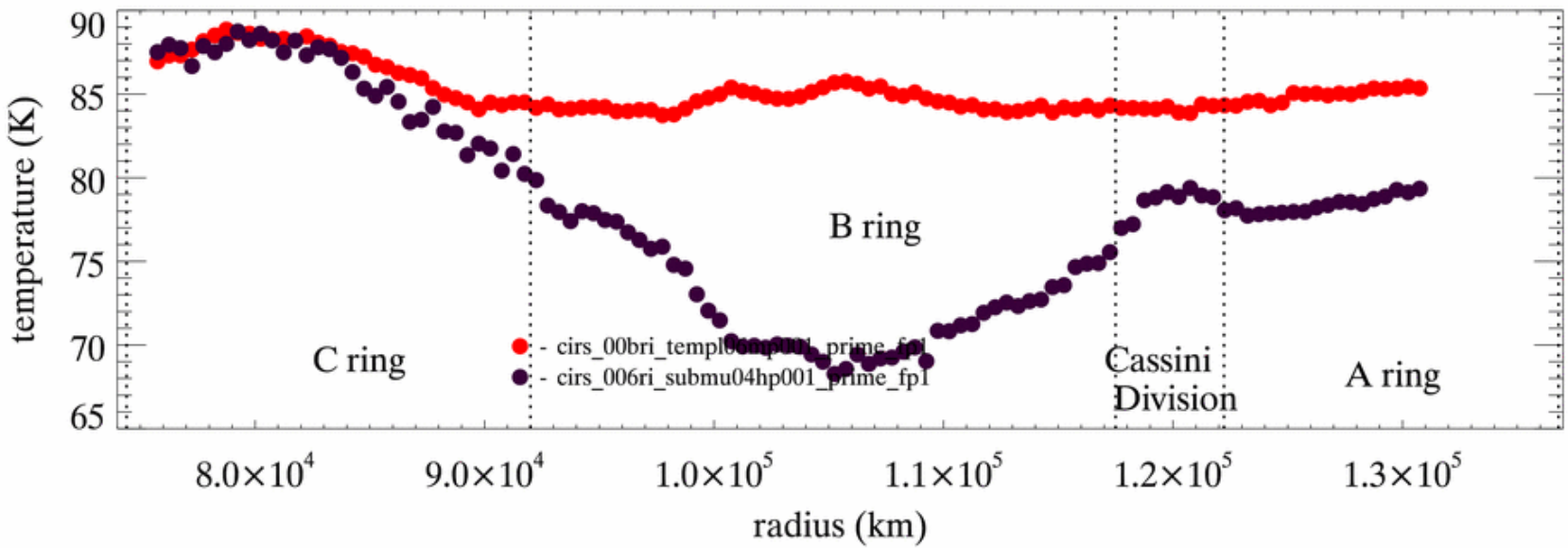
Geometry Data for CIRS Scans

Observation Type	Start Time	Duration (hr:min)	Solar Inc. (deg)	Range (Rs)	Emission Angle (deg)	Phase Angle (deg)	Hour Angle
Lit Low Phase	2005-104T06:54	02:57	-22.01	9.143 10.667	97.09 97.32	26.83 35.81	239.90 240.0
Lit High Phase	2004-350T21:36	01:32	-23.13	9.817 10.499	96.13 96.47	130.49 137.38	311.56 315.95
Unlit Low Phase	2004-349T19:57	01:32	-23.14	7.453 7.439	83.41 83.55	47.50 60.40	122.72 129.74
Unlit High Phase	2005-105T11:56	01:28	-22.00	9.362 9.773	86.47 86.69	131.50 140.49	142.29 142.32

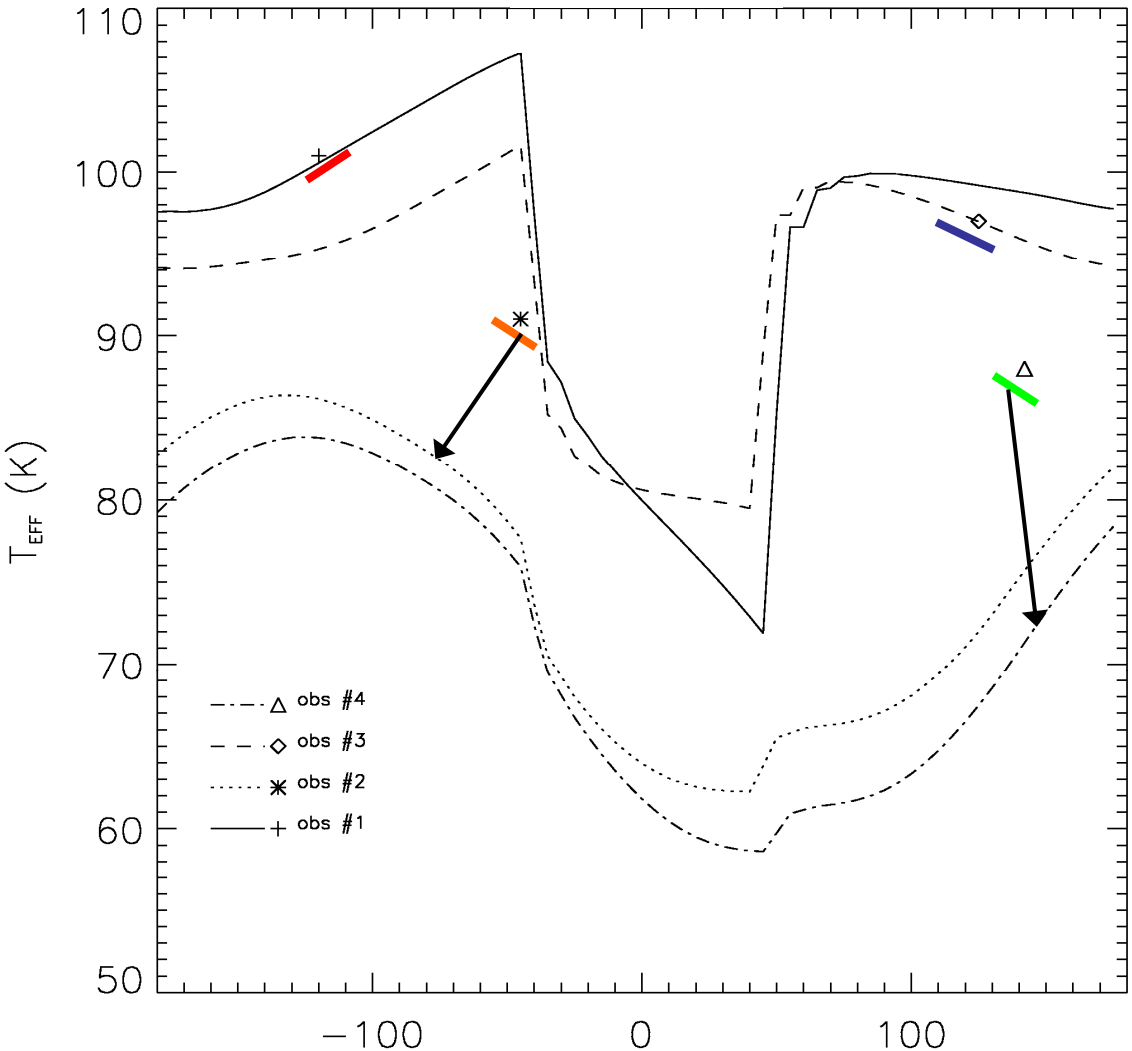
Scans selected with comparable ring opening

ΔT: Lit High Phase - Unlit High Phase



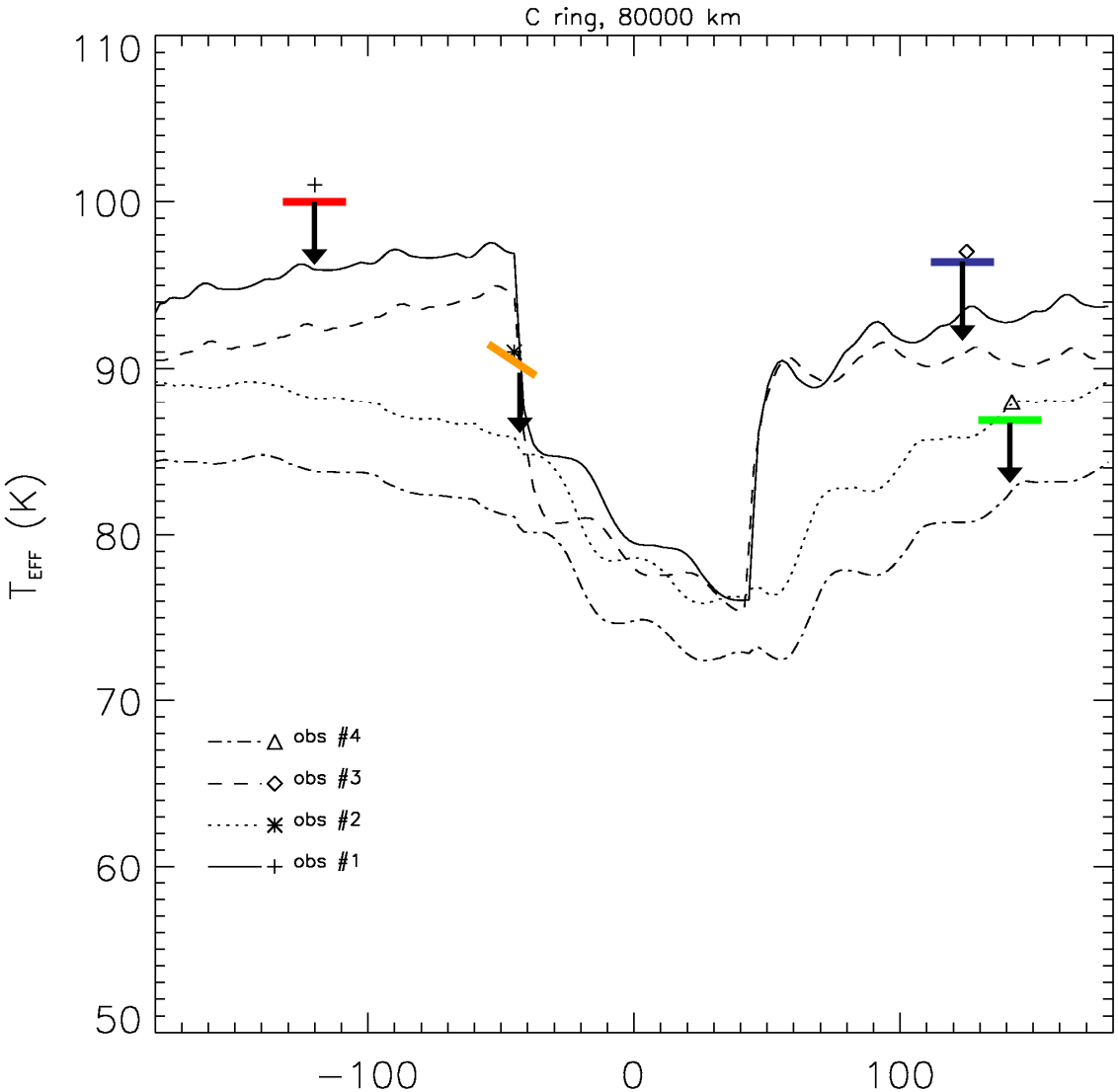


C Ring: 80,000 km, Slow Rotators (1 Ω: Synchronous rotators)



- Low phase (/ /): slow rotator model fits data points
- High phase (/ /): model curves are too cold compared to data points

C Ring: 80,000 km, Fast Rotators (0.1 Ω)



- Low phase (/ /): fast rotator model too cold compared to data points
- High phase (/ /): fast rotator model too cold compared to data points