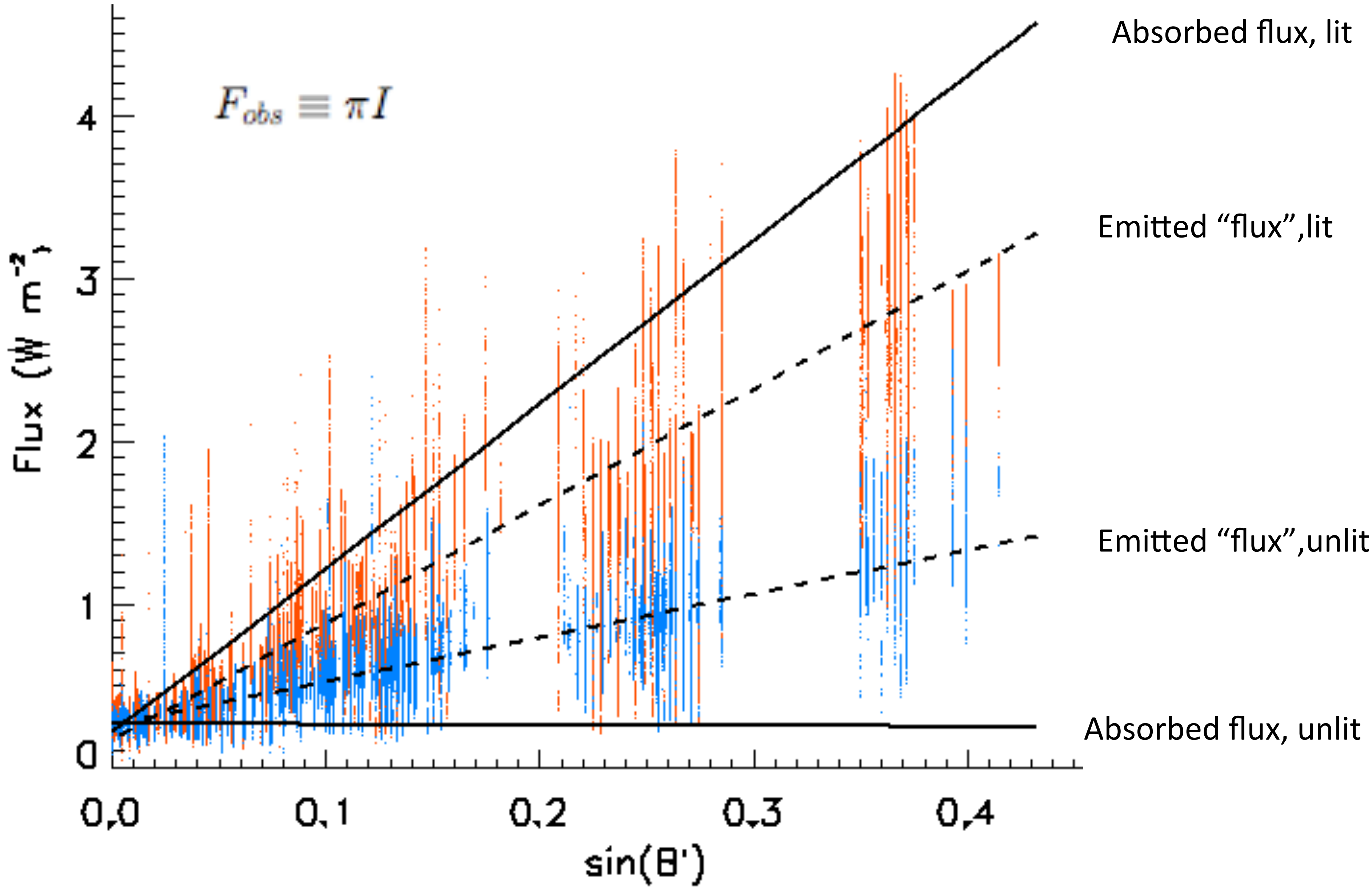
Thermal Transport in the B Ring

Stuart Pilorz, SETI
Nicolas Altobelli, ESA
Josh Colwell, UCF
Mark Showalter, SETI

Boulder, CO 13 Aug 2014

(SUMMARY:)


$F_{obs} \equiv \pi I$
Flux (W m^{-2})
sin(θ')
0
1
2
3
4
0.0
0.1
0.2
0.3
0.4
Absorbed flux, lit
Emitted "flux",lit
Emitted "flux",unlit
Absorbed flux, unlit

I. Model for incident flux

a) Flux onto plane above rings

b) Flux absorbed by rings

II. Derive emitted flux from observed intensities

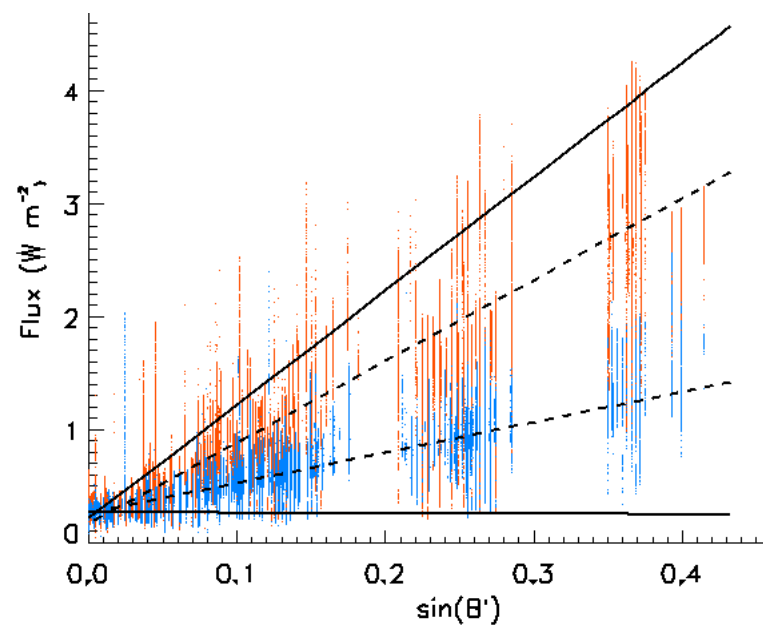
a) unlit: isotropic radiation

b) Lit: use simple model for hotspot emission

III. Energy budget

a) Throughput

b) Conductivity

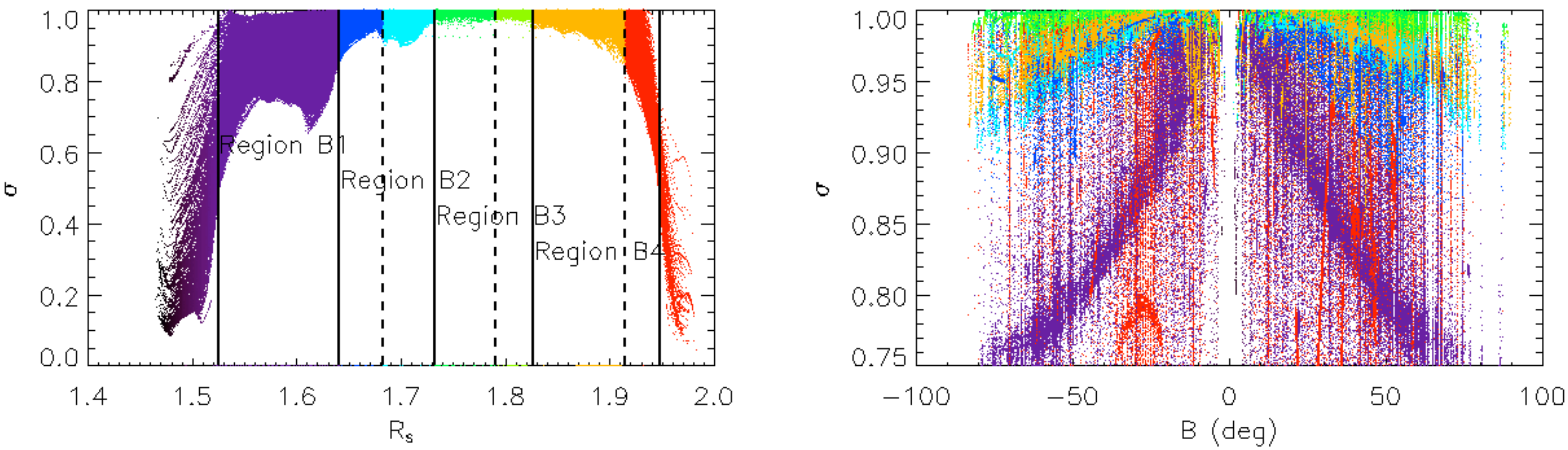


b) Absorption into rings:

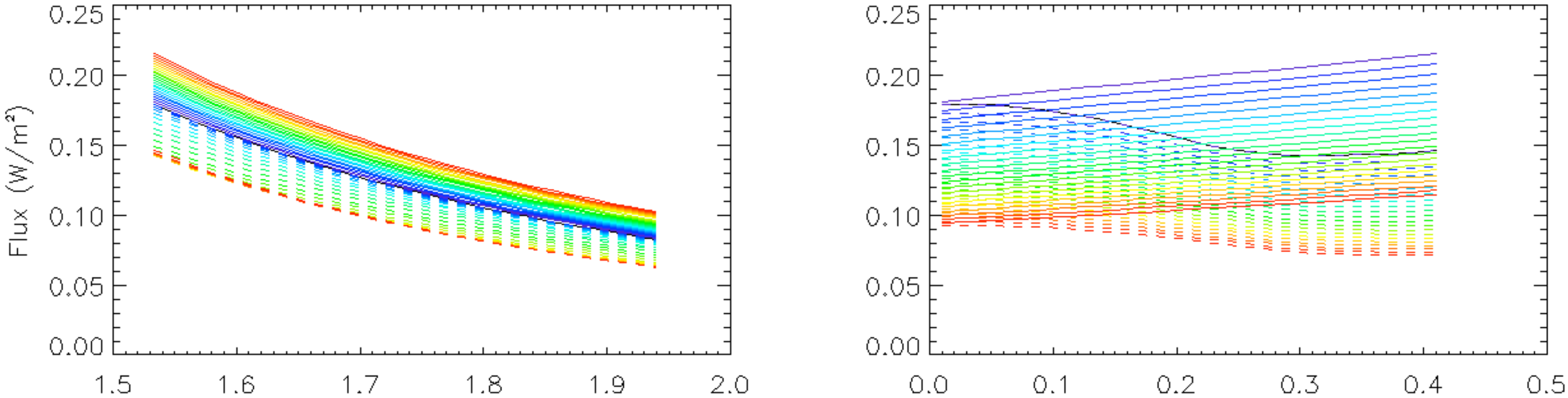
(i) albedo

(ii) cross section

Ring regions by cross section behavior:

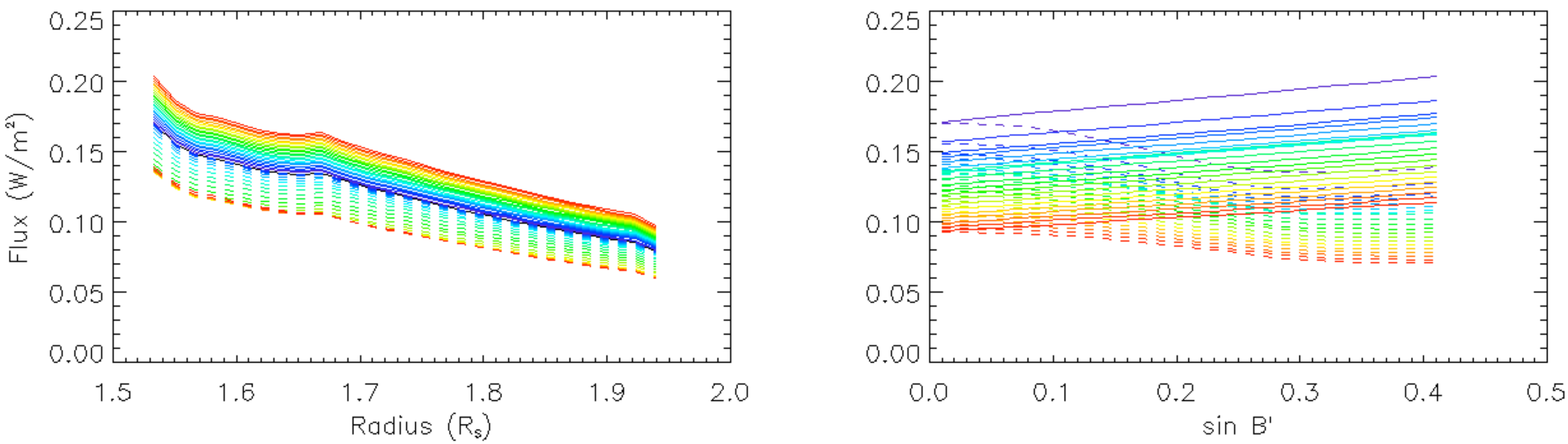


Flux Model: Saturn-reflected component of absorbed flux:

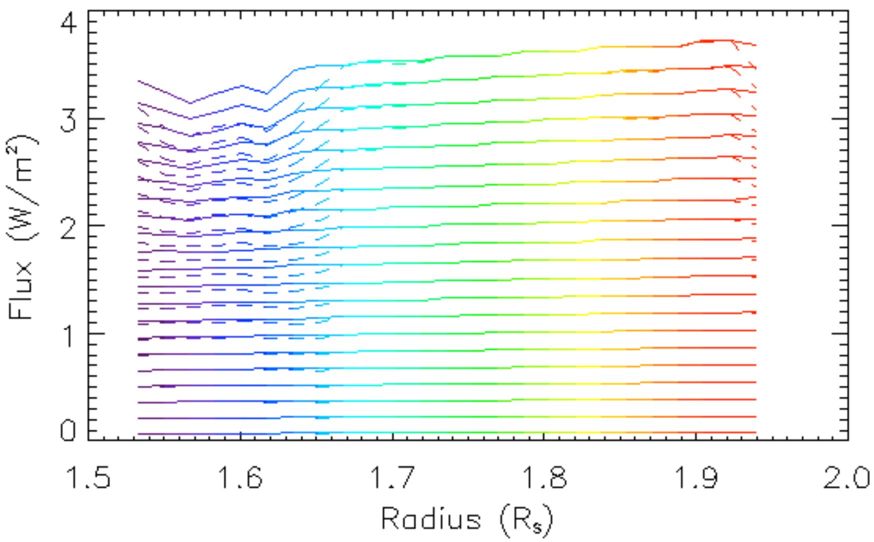


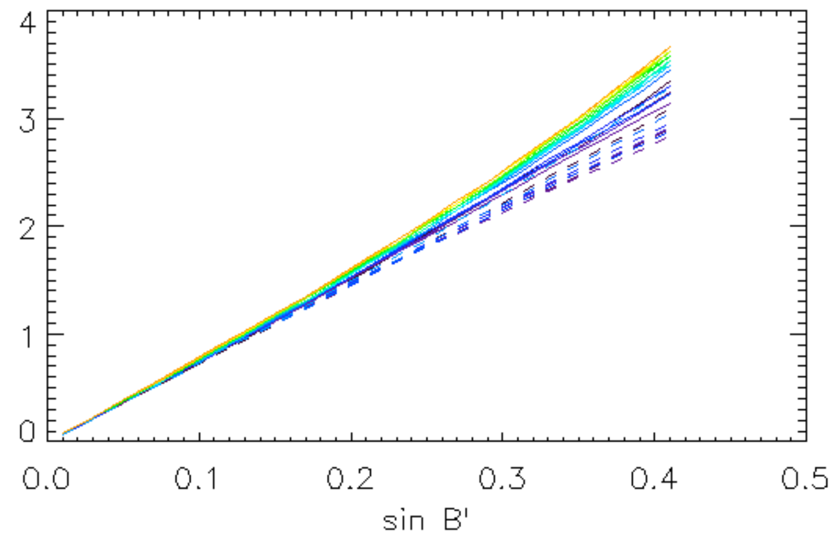
Colored by epoch

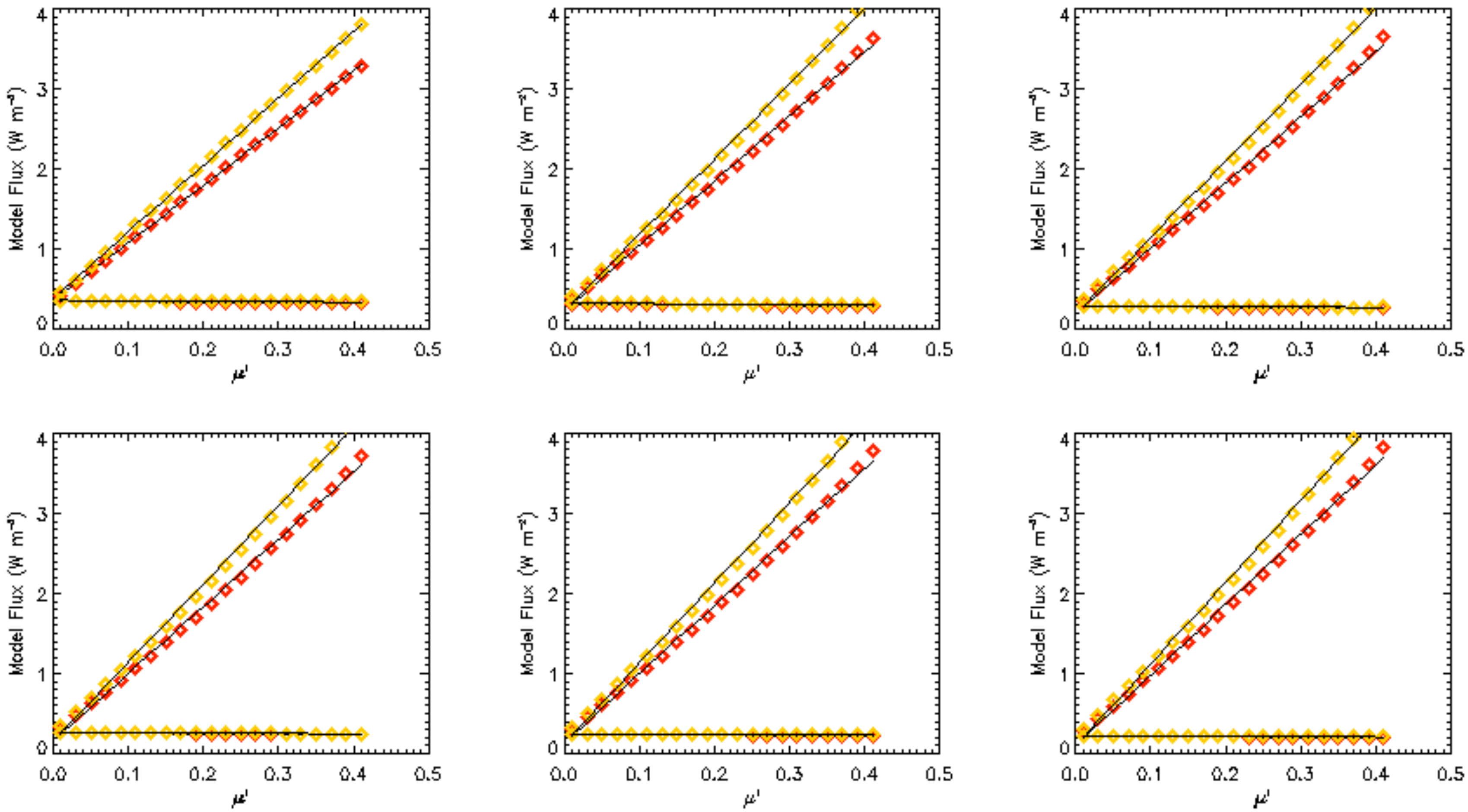
Colored by radius

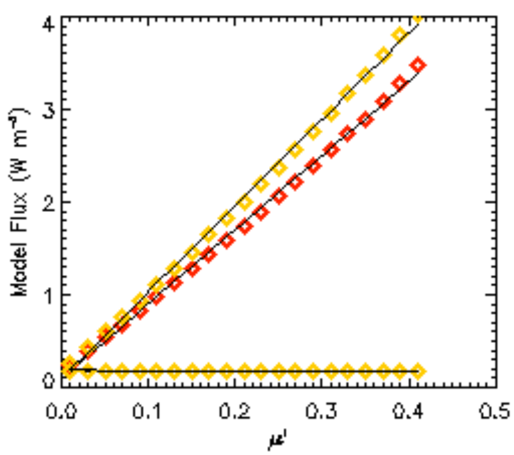


Model: Solar contribution









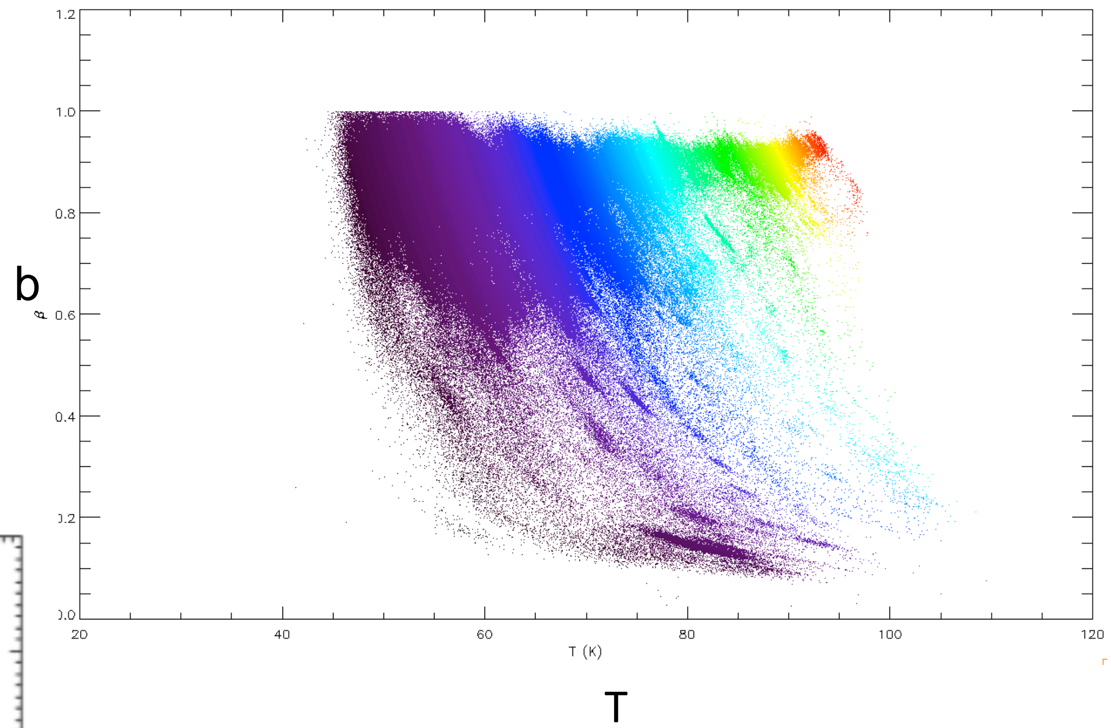
Model Summary:

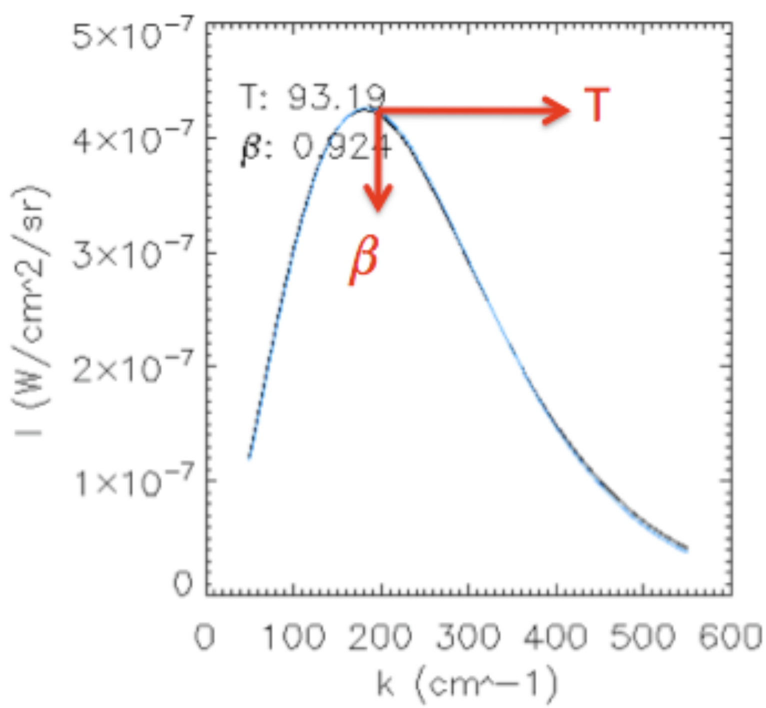
Inicident+absorbed flux by ring region:

gold: A = 0.3

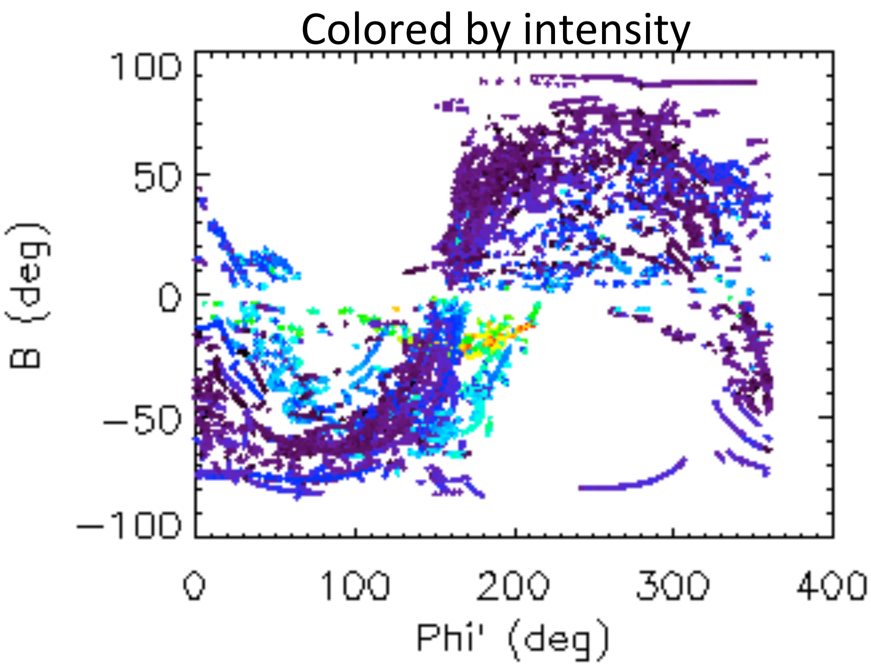
red: A = 0.4

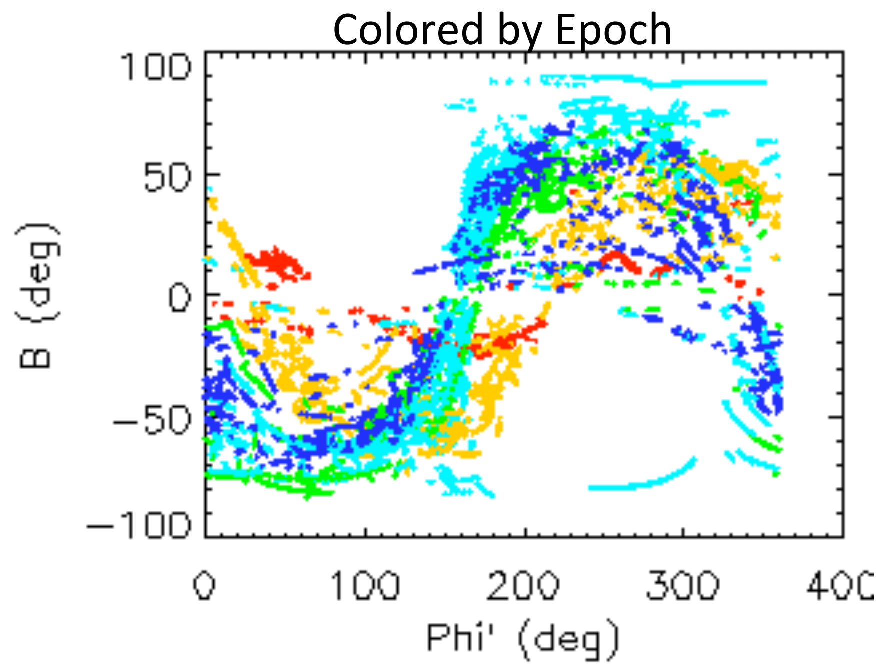
DATA:
Total Intensity is more robust than temperature and emissivity.

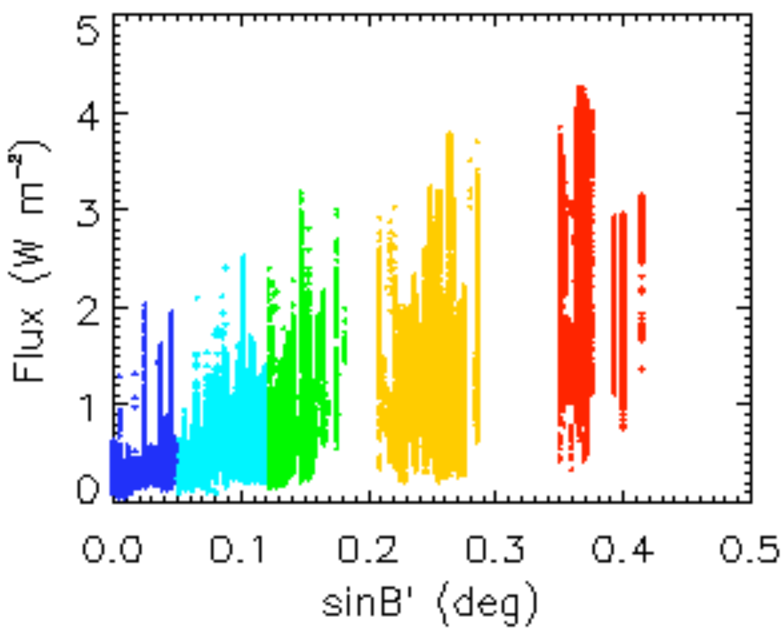




$$I(k) = B(k, \overline{T})\beta$$



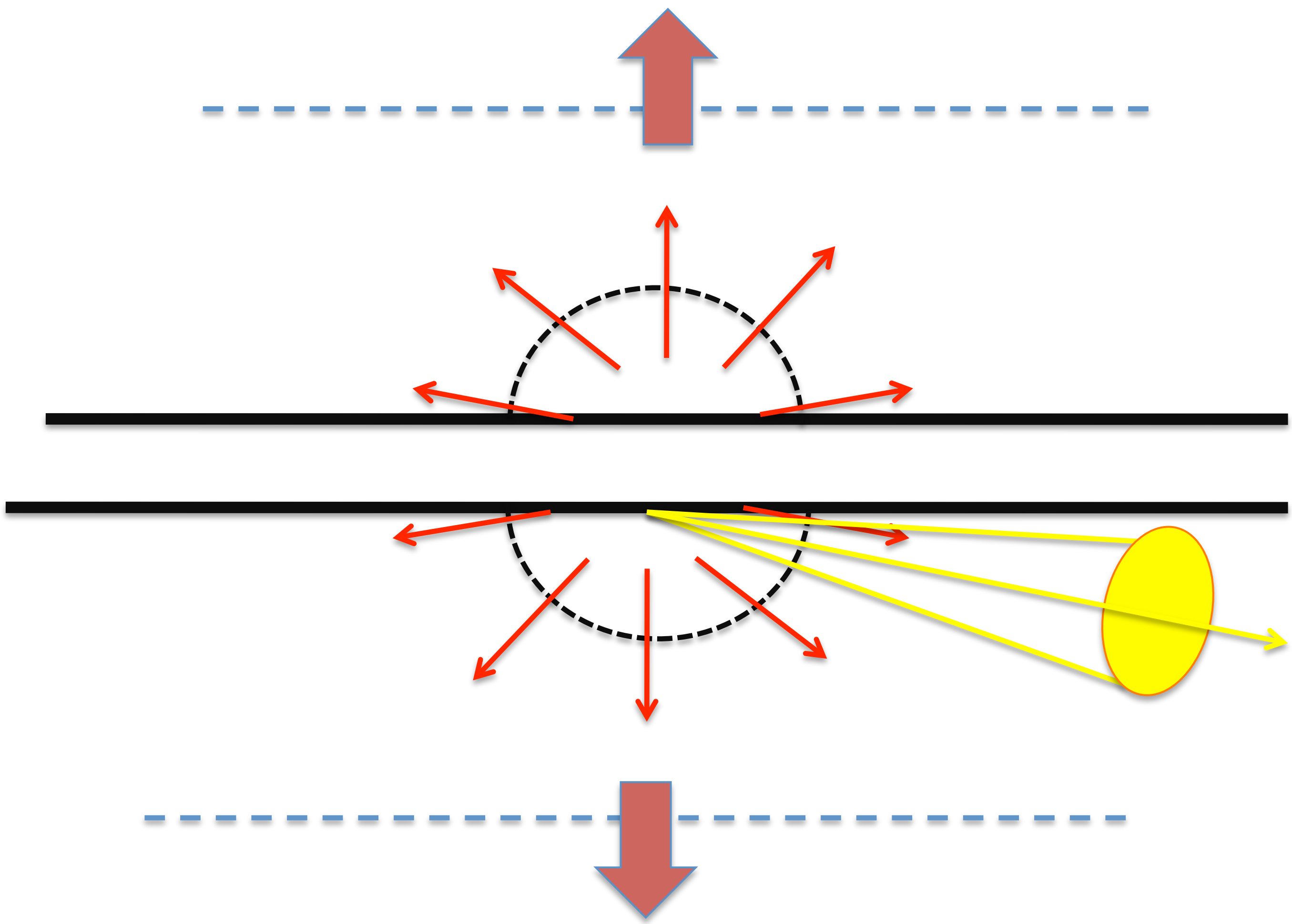


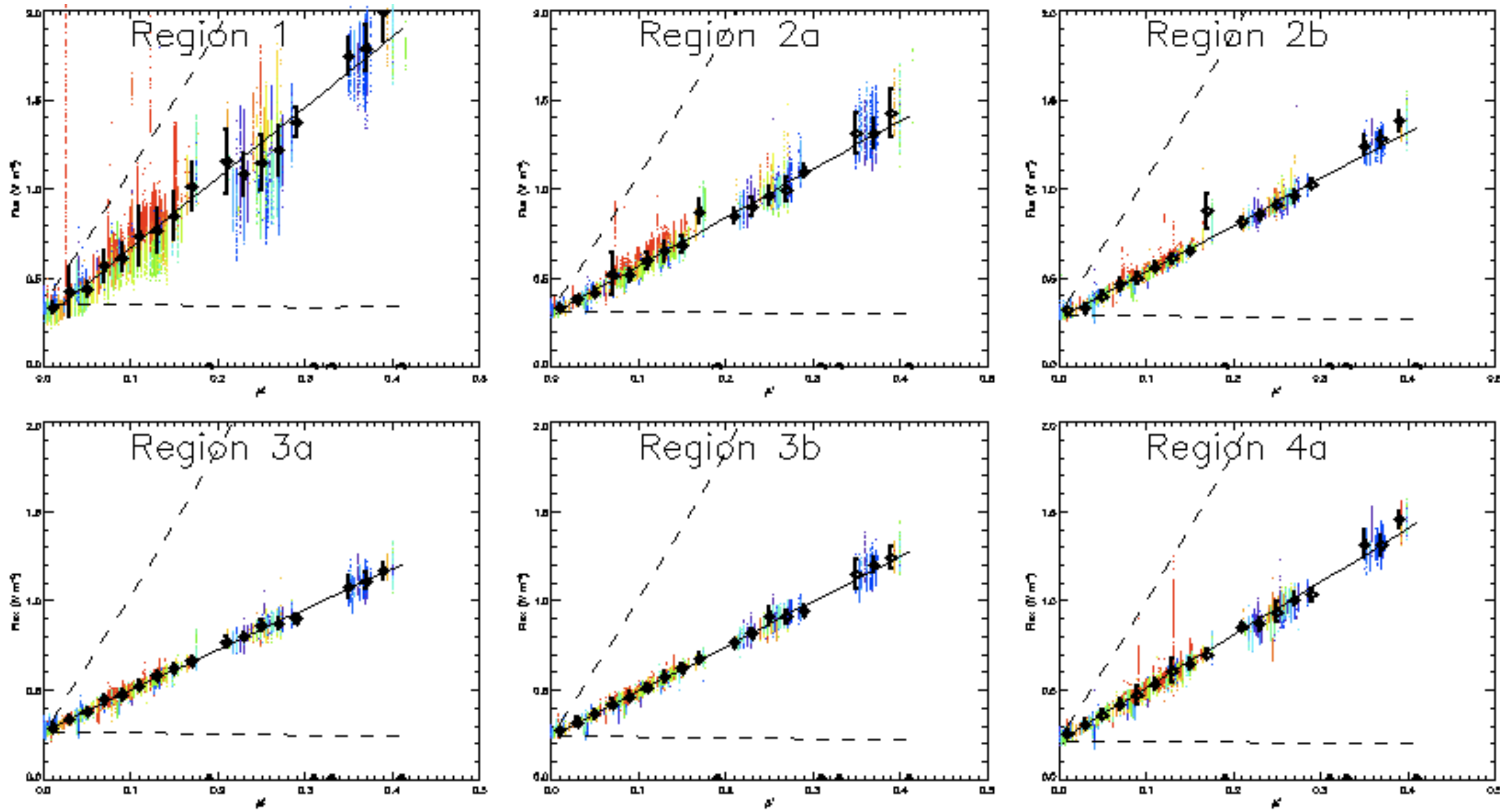


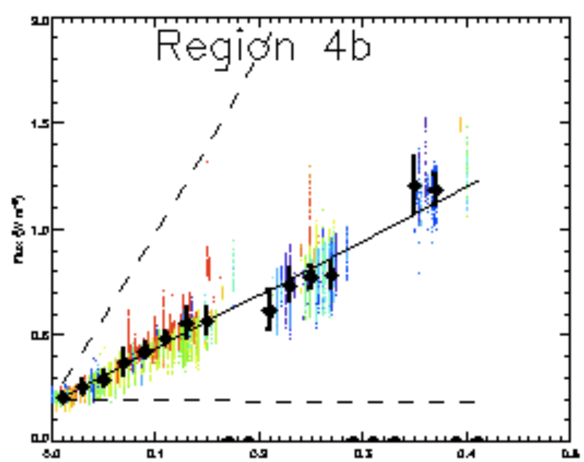
There is significantly incomplete sampling in emission direction.

Most Cassini orbits throughout the mission are somewhat the same.

One can't integrate directly:
Assume a simple model for emission and check it against the data:



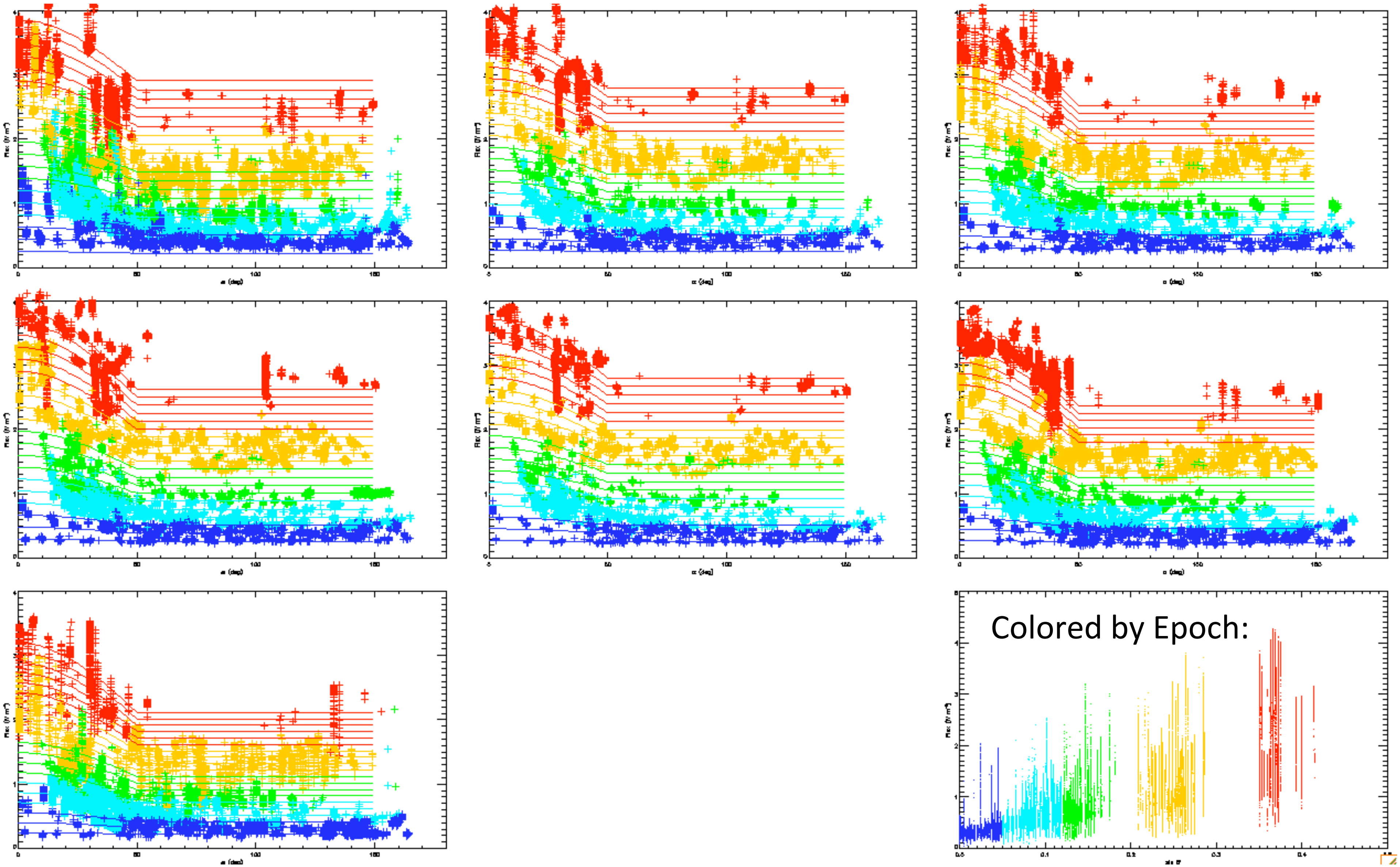


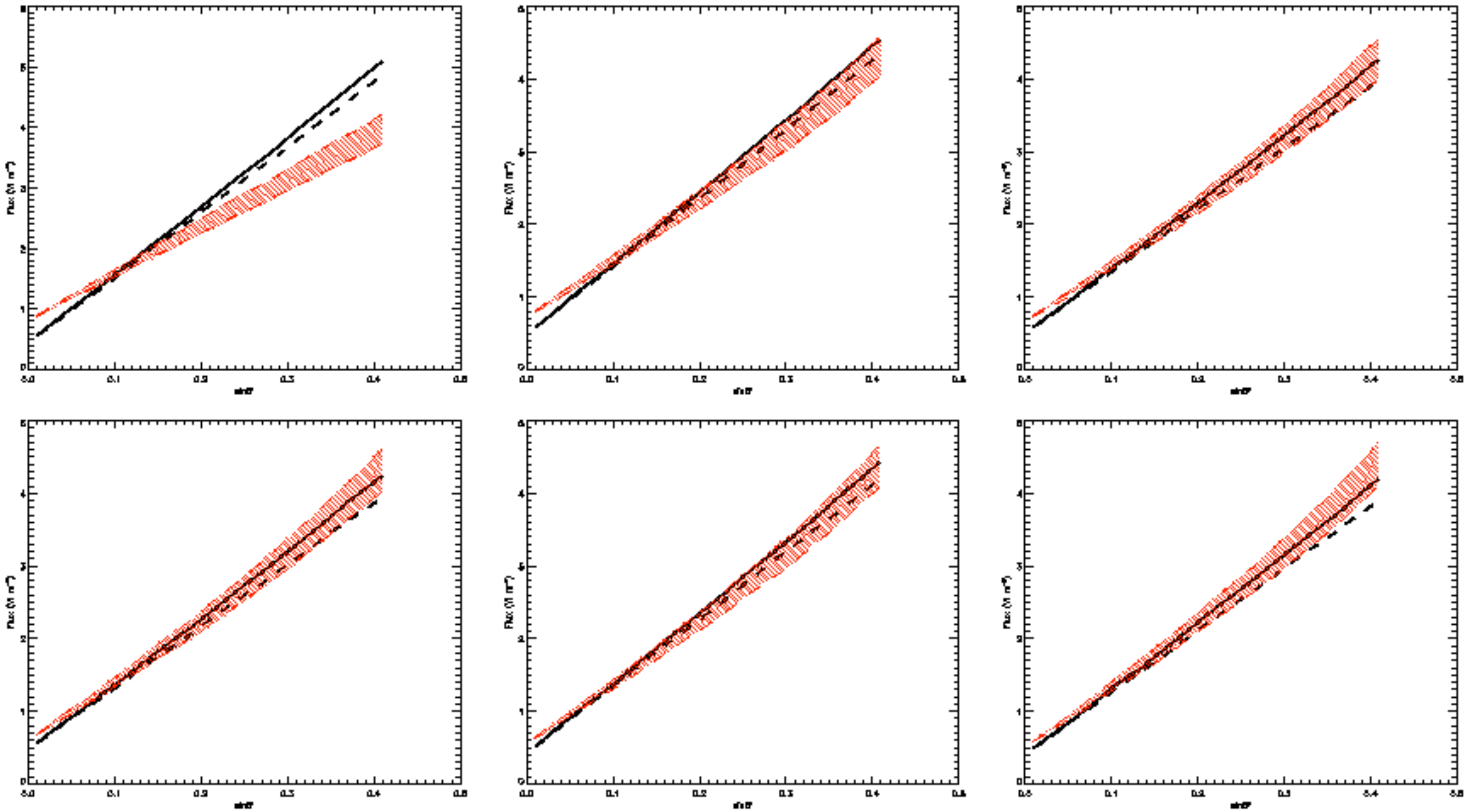


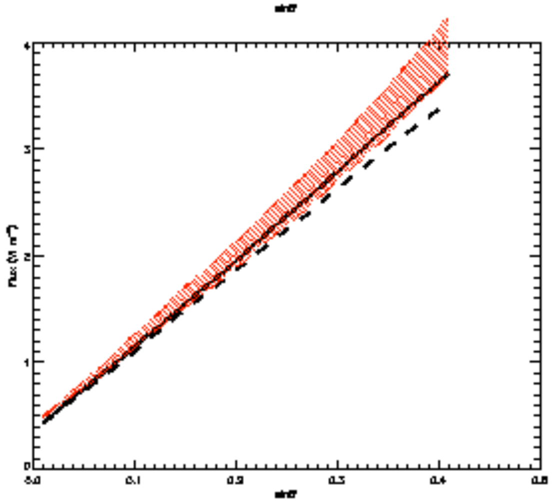
UNLIT Emission:

$R^2 > 0.97$ means only 3% of the variance
Is NOT explained by solar elevation.
Conclude: pretty much isotropic emission.

LIT SIDE EMISSION: It appears isotropic at HIGH phase….



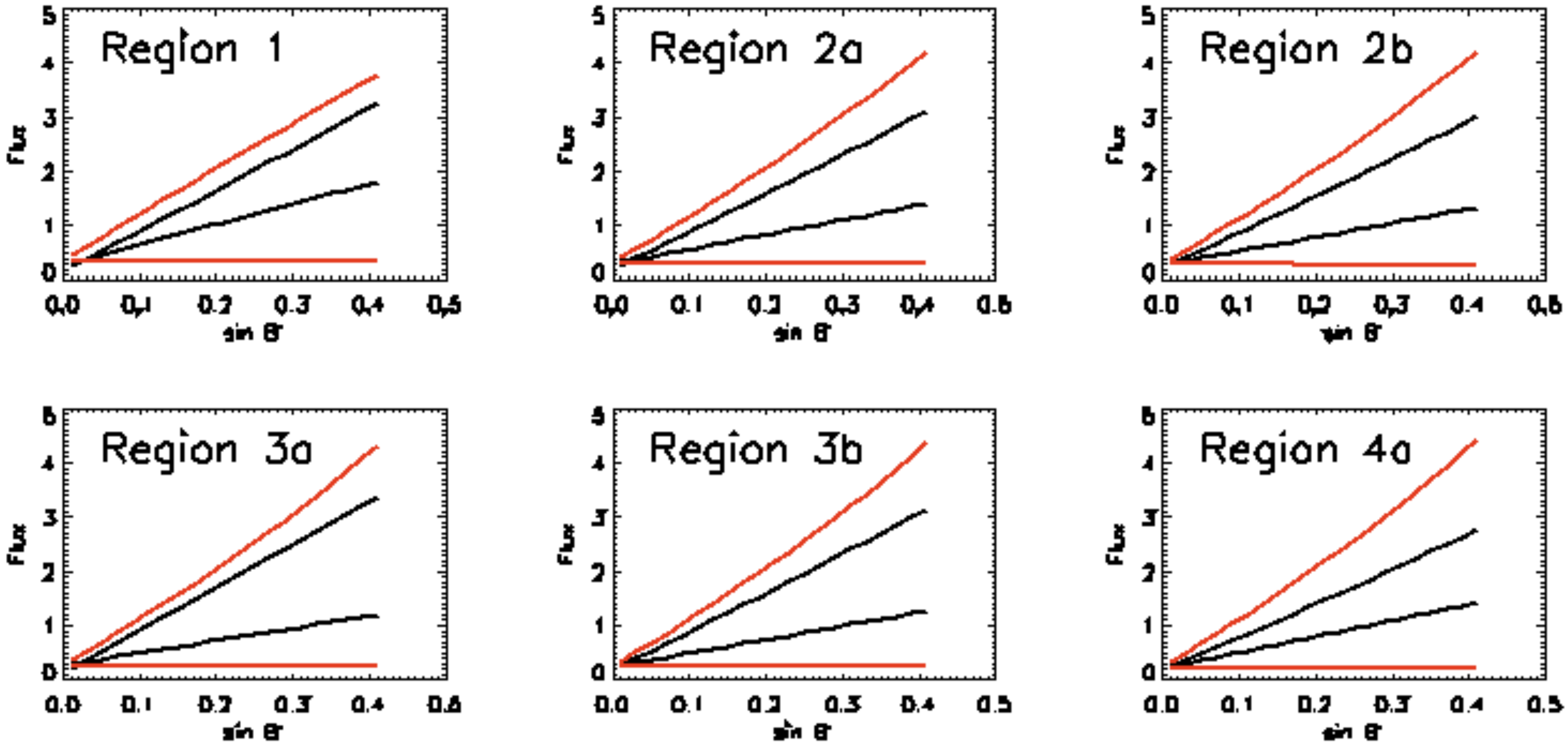


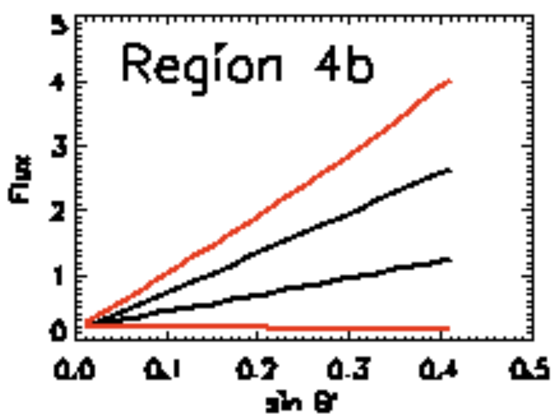


ENERGY BUDGET:

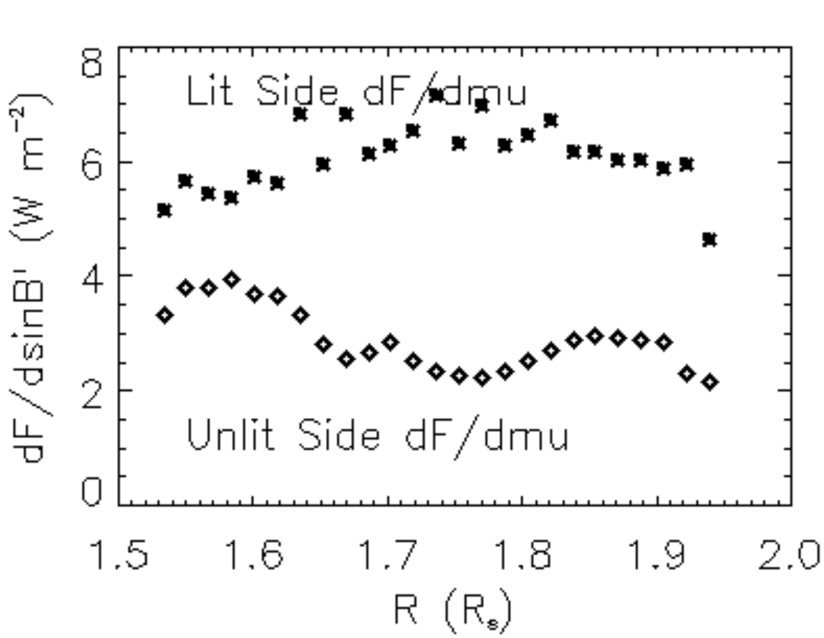
Black: estimated total emitted flux

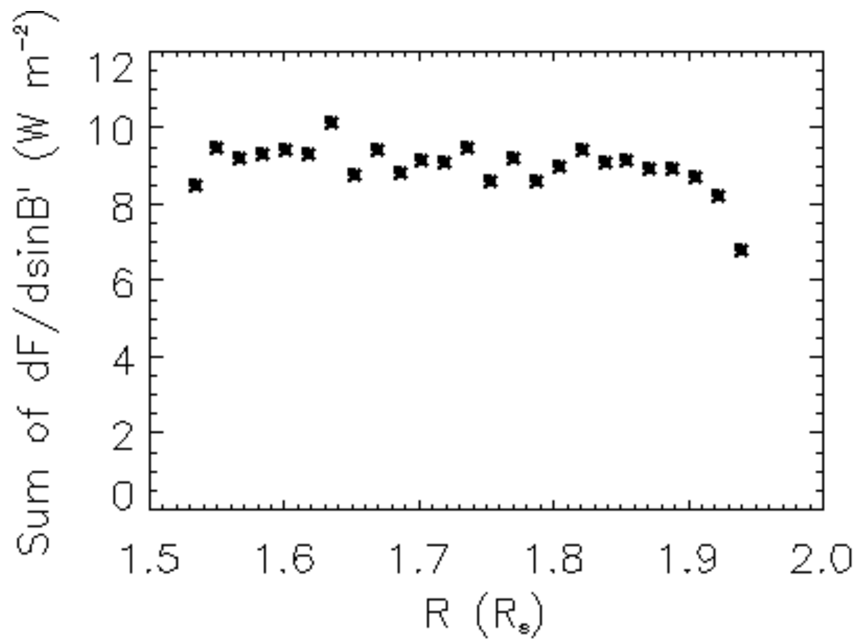
Red: modeled total incident+absorbed flux

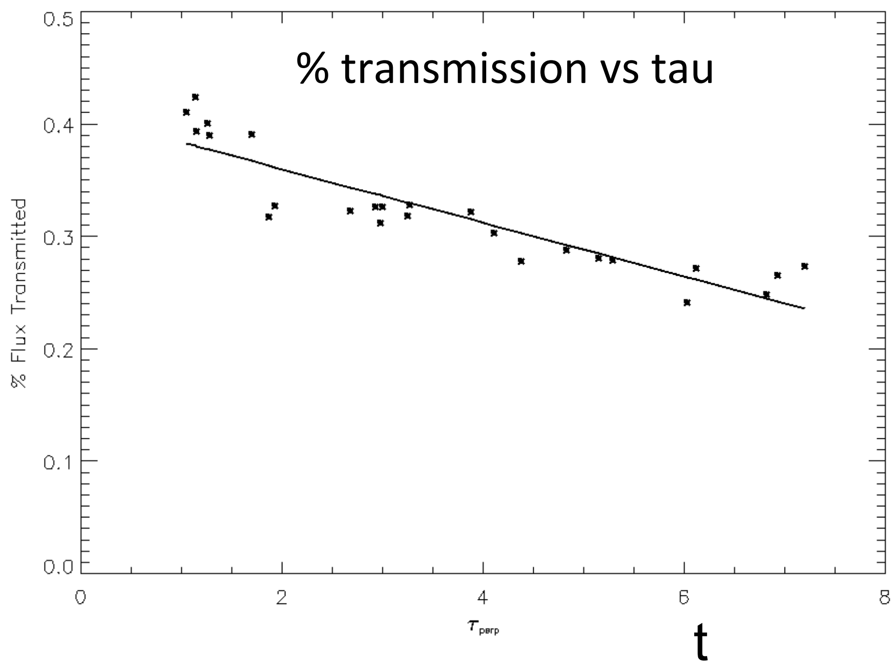




Incident and emitted flux:
Sum of slopes for unlit flux ~ E0 (1-A)s



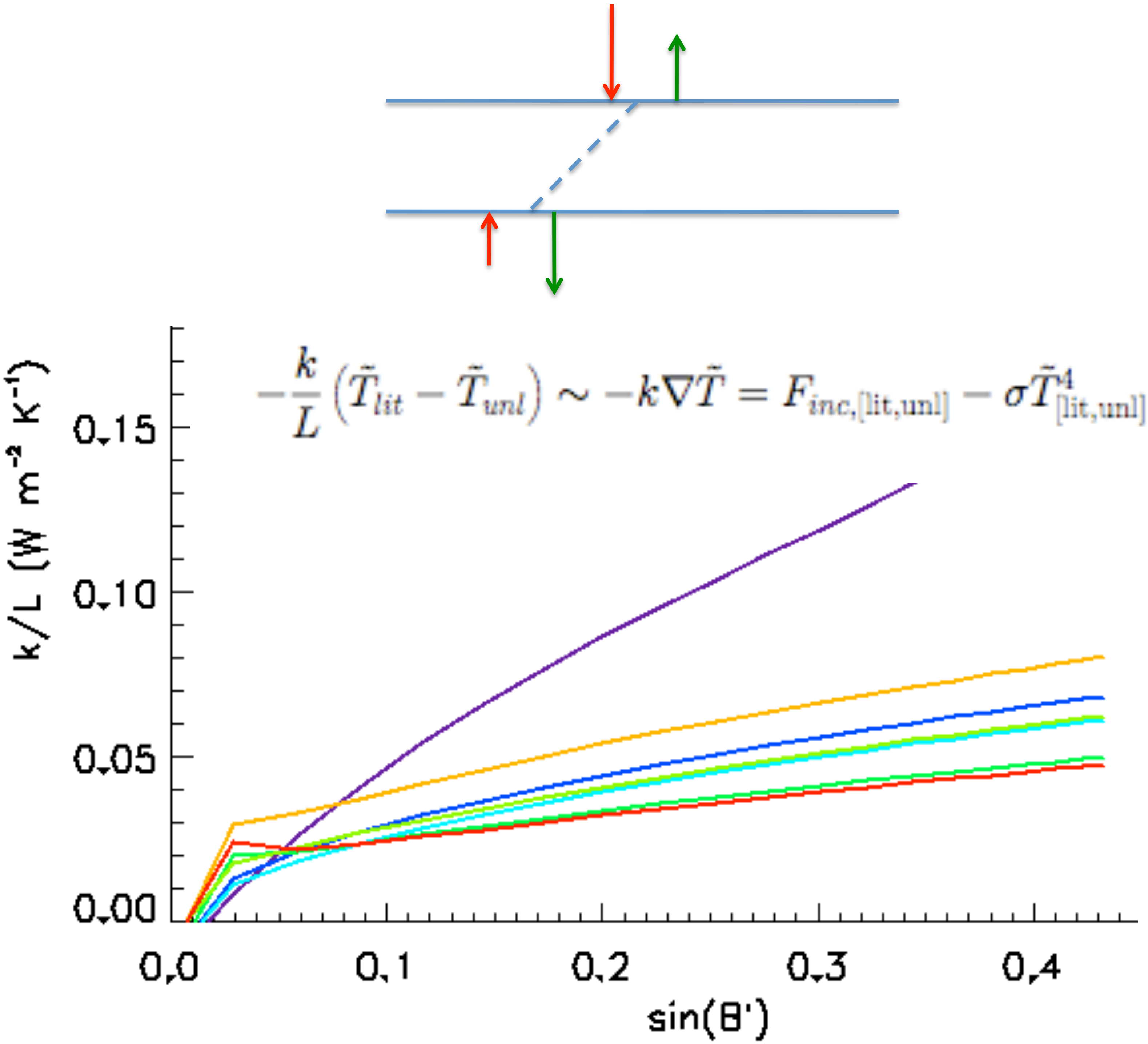


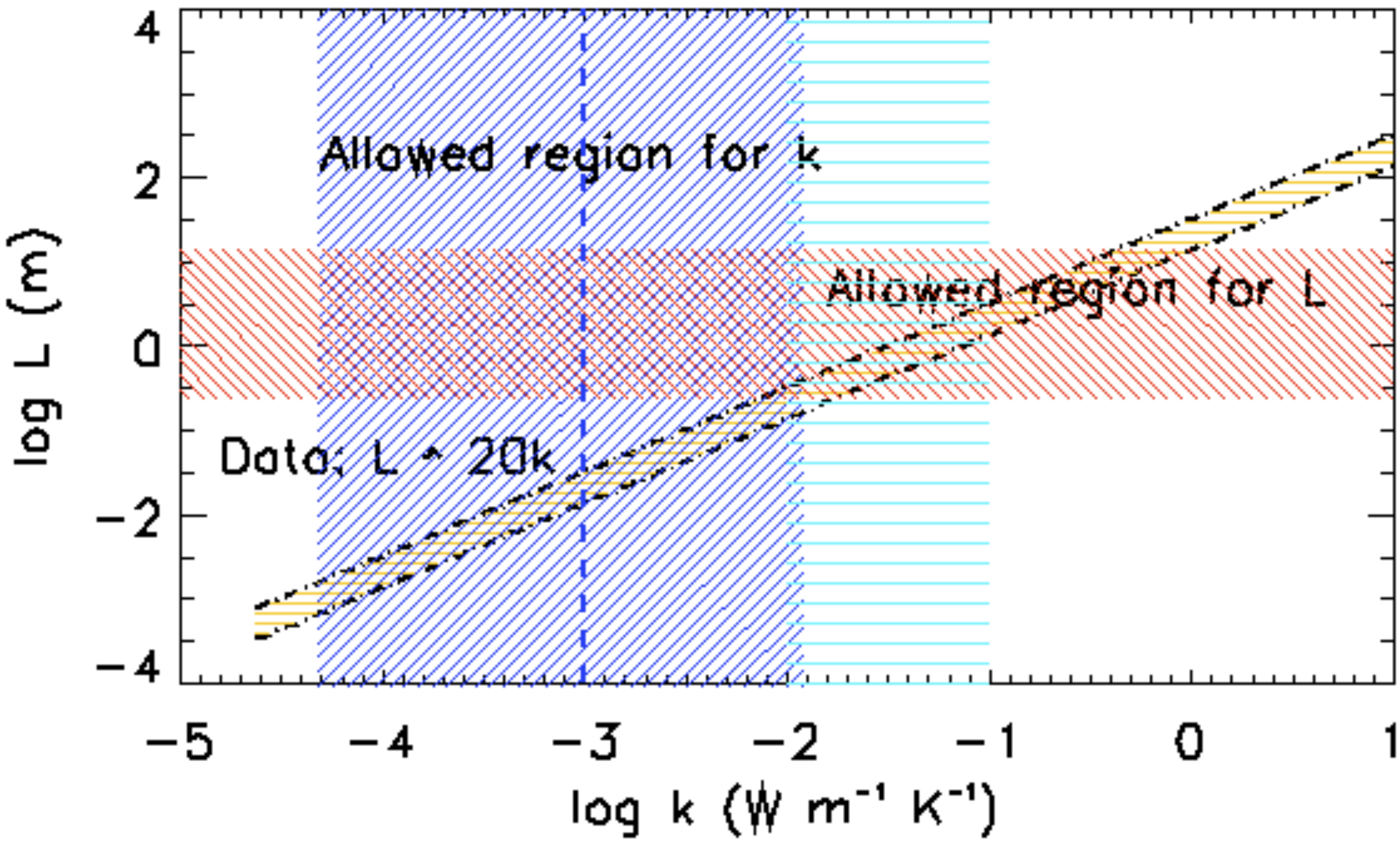


% transmission is expressed as a ratio of slopes:

$$f = \text{unlit} / (\text{lit} + \text{unlit})$$

$$= \text{b\_lit} / (\text{b\_lit} + \text{b\_unlit})$$

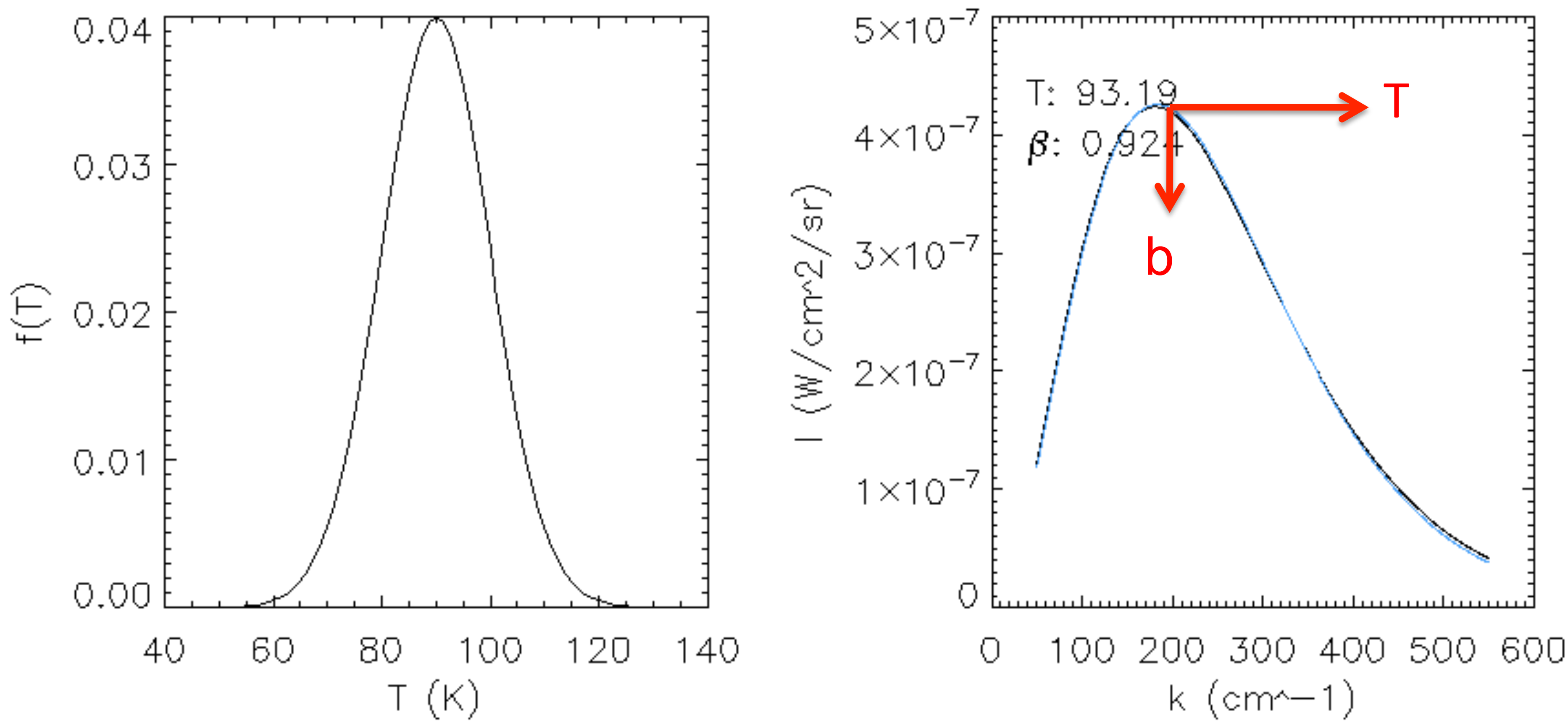

$-\frac{k}{L}\left(\tilde{T}_{lit}-\tilde{T}_{unl}\right)\sim -k\nabla\tilde{T}=F_{inc,[\mathrm{lit,unl}]}-\sigma\tilde{T}^{4}_{[\mathrm{lit,unl}]}$
k/L (W m^{-2} K^{-1})
0.00
0.05
0.10
0.15
0.0
0.1
0.2
0.3
0.4
sin(θ')


Allowed region for k
Allowed region for L
Data: L ^ 20k
log L (m)
log k (W m⁻¹ K⁻¹)
4
2
0
−2
−4
−5
−4
−3
−2
−1
0
1

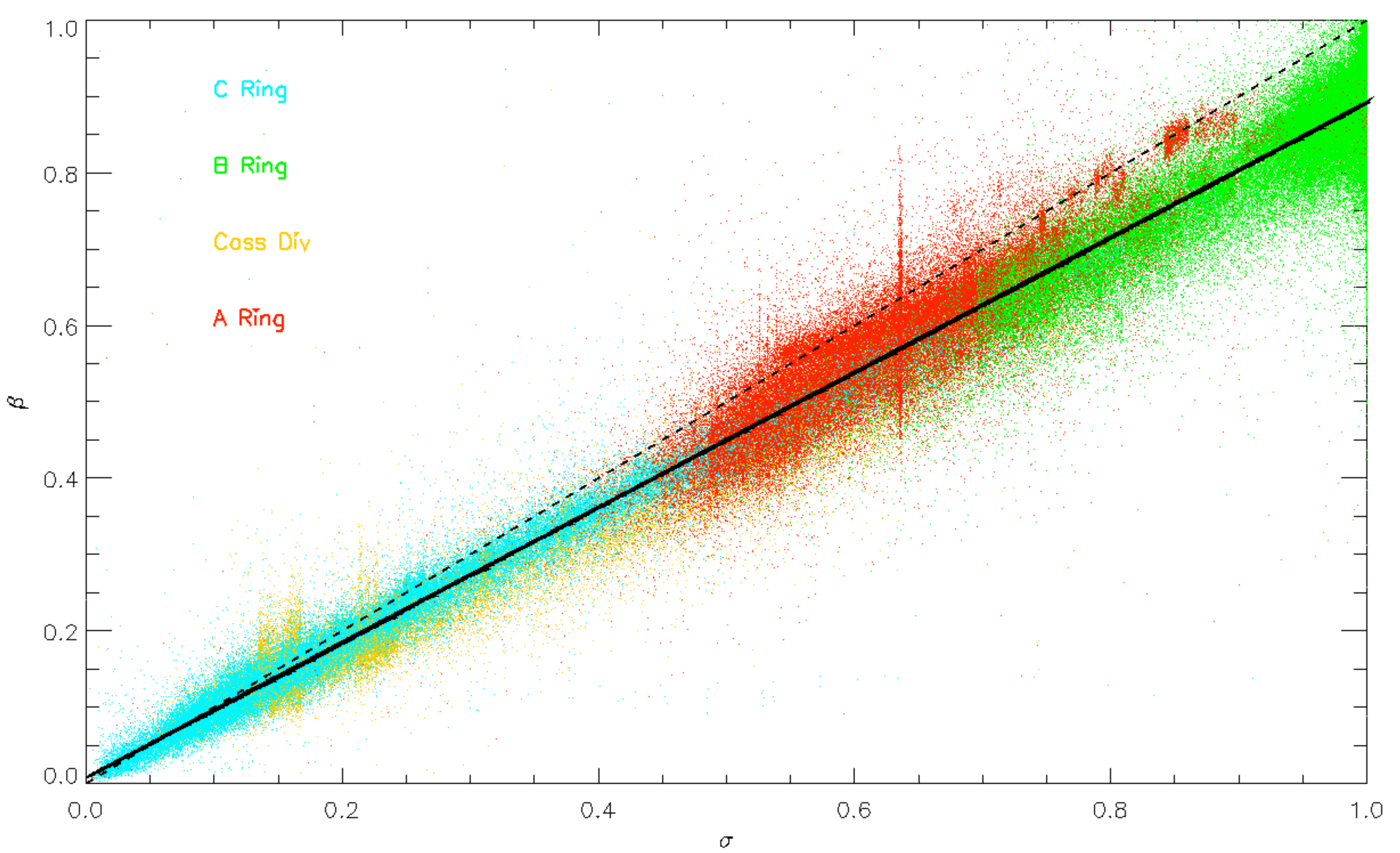
Conclude:

a) Energy budget seems to sum up for the B ring
b) Unlit side emits isotropically, lit side has a phase surge which contributes only a small amount to net flux
c) B ring transmits 30-40% of energy incident on lit side to th unlit side on short timescales
d) The throughput is weakly linearly dependent on optical depth
e) Simple assumptions about equilibrium heat transfer indicate a thermal conductivity for the ring that is very high
f) We still haven't answered whether the conductivity is due to mechanical transfer or efficient coupled radiative-conductive processes.

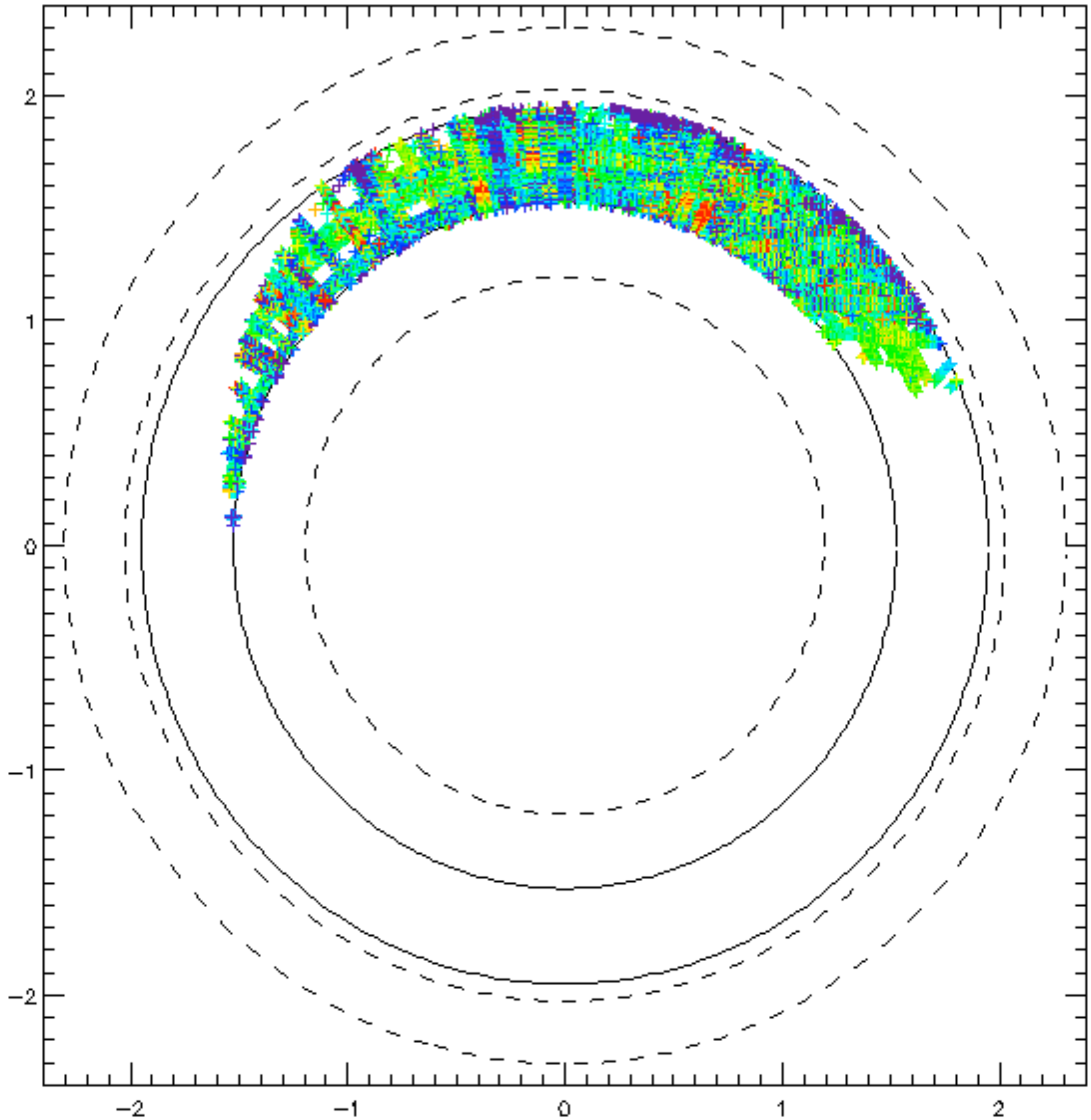
Fin

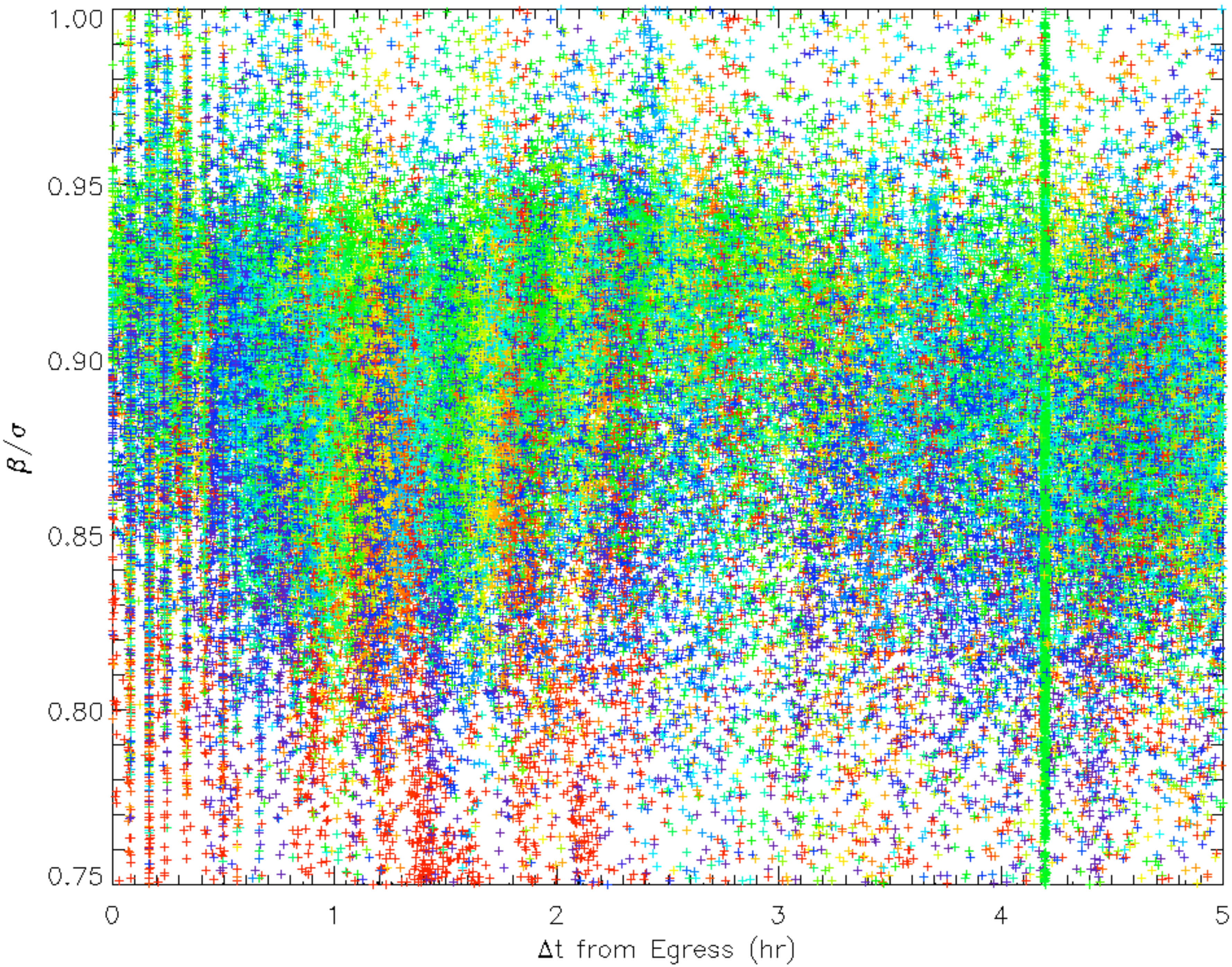


f(T)
0.04
0.03
0.02
0.01
0.00
40
60
80
100
120
140
T (K)
I (W/cm^2/sr)
5×10^-7
4×10^-7
3×10^-7
2×10^-7
1×10^-7
0
T: 93.19
β: 0.924
T
b
0
100
200
300
400
500
600
k (cm^-1)



C Ring
B Ring
Cass Div
A Ring
β
σ
0.0
0.2
0.4
0.6
0.8
1.0


2
1
0
−1
−2
−2
−1
0
1
2



1.00
0.95
0.90
0.85
0.80
0.75
β/σ
0
1
2
3
4
5
Δt from Egress (hr)

1. “Flux” behaves like we expect a flux to.

2. Rings emit isotropically

3. Flux balance sums up

4. Tells us conductivity is high

5. Is there mechanical transport, or just coupled radiative/thermal?