Total Solar Irradiance and Solar Luminosity

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TSI on SOLAR-C(A) — Science Goals

- Solar luminosity
  - Variability over the solar cycle?
  - Standard Solar Model boundary condition
  - Stellar evolution theory
- Meridional circulation and north-south asymmetries of the solar activity (dynamo)
  - Meridional temperature gradient
  - Discriminate between different models for latitudinal dependency of TSI variability

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Luminosity ↔ Stellar Structure

- Steady-state assumption: $\frac{dL}{dr} = 4\pi r^2 \rho (\epsilon - \epsilon_\nu)$
- Solar Luminosity: $L_\odot = 4\pi r_\odot^2 \sigma T_{surface}^4 = 4\pi r_\odot^2 \int \rho (\epsilon - \epsilon_\nu)$
- $T_{surface}$ is linked to T_{core} via energy production process (p-p chain efficiency scales with T_{core}^4)

➔ Accurate measurement of $L_\odot$ thus allows us to determine the solar *surface* and *core temperatures* and to validate the Standard Solar Model and stellar evolution theory

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Observational Requirements for Solar Luminosity

- ✔Integrated disk measurements
- ✔High heliographic latitude
  - ✔At 40° the effect of the polar areas appears with 64% of its amplitude
- ✔Low noise level
  - ✔thermal stability
  - ✔temporal stability

Additional Benefits — Meridional Temperature

- Meridional temperature measured with HINODE suffers from uncertainty in photometric calibration of the images
- Integrated-disk measurements of TSI at different latitudes eliminate this problem
- 1K ~ 1 Wm^{-2} (~700 ppm)

Latitudinal Heat Flow

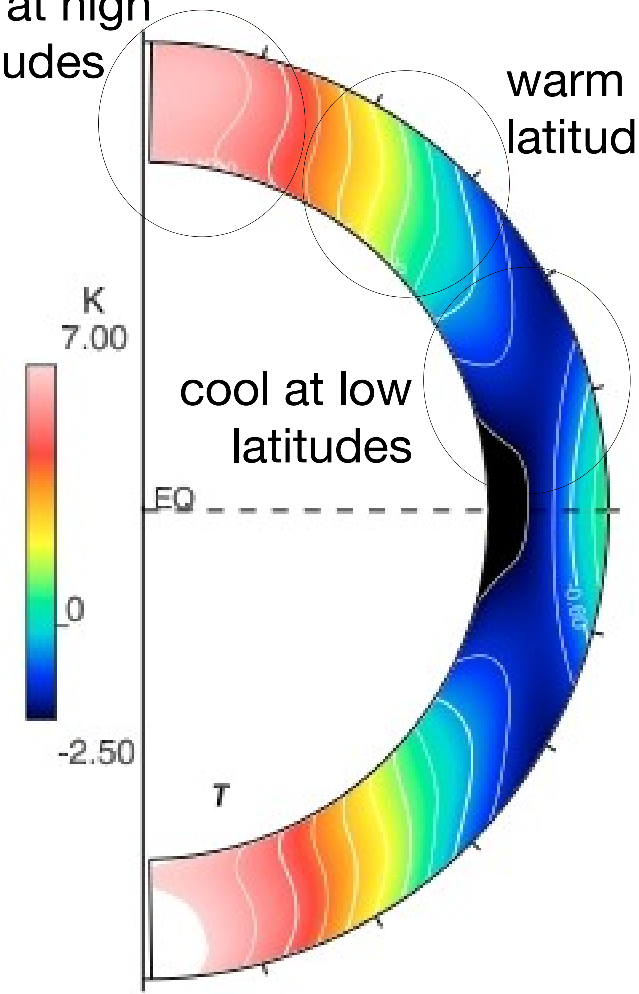
- Conical (rather than cylindrical) rotation profile is indicative of latitudinal heat transfer and/or thermal forcing from the tachocline [Miesch et al., 2006]
- Variability of order of 1 – 10 K have been predicted by simulations and measured by helioseismic inversions [Brun et al., 2010]

Simulations vs. Observations

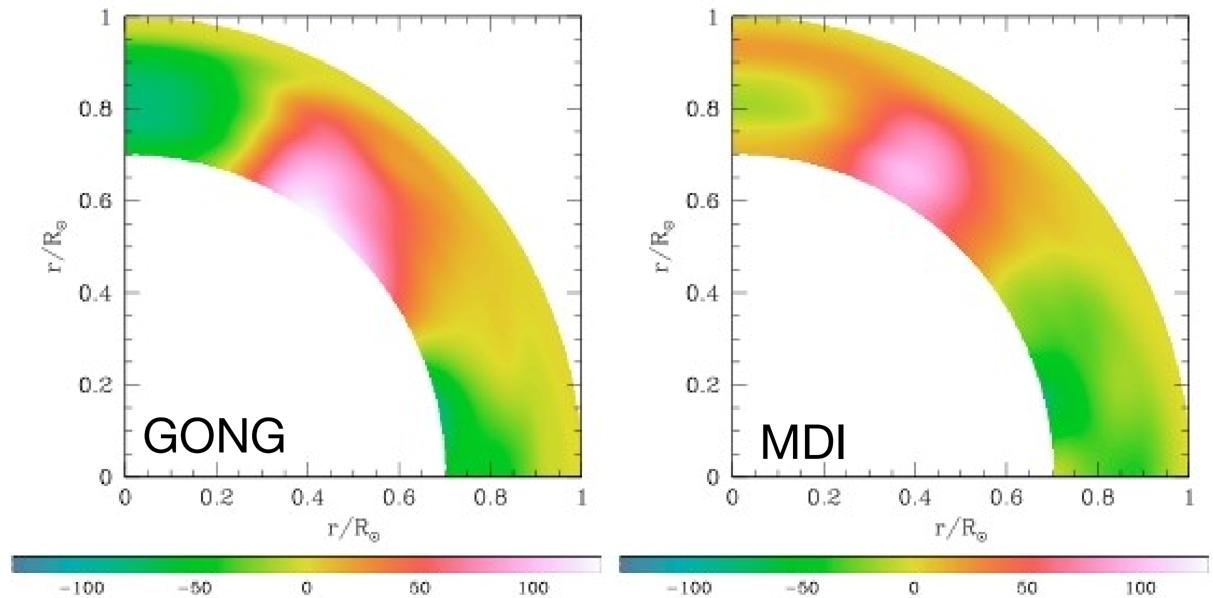
hot at high latitudes

warm at mid latitudes

cool at low latitudes

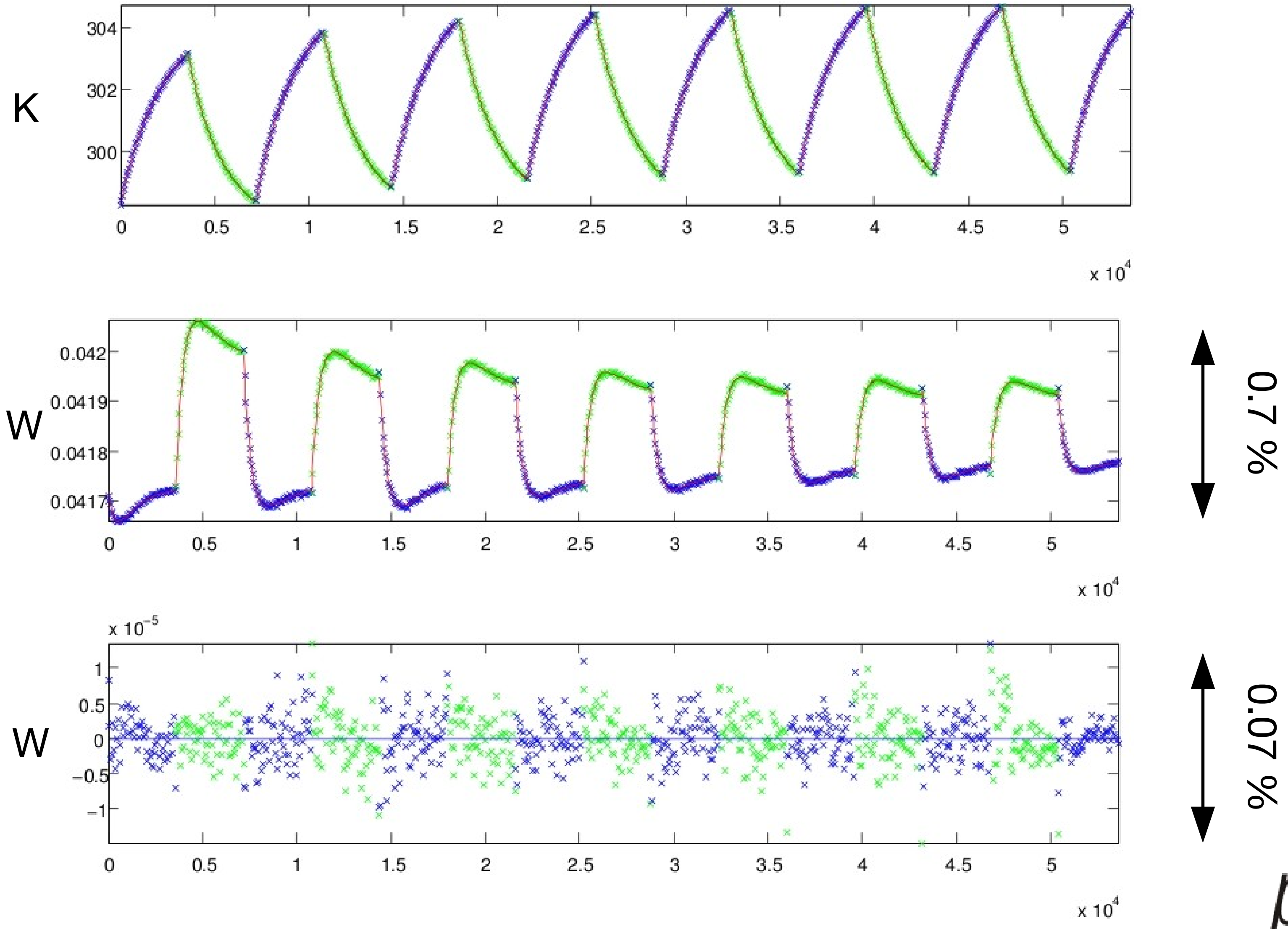


cool at low *and high* latitudes
warm at mid latitudes
δT≈10 K near the surface

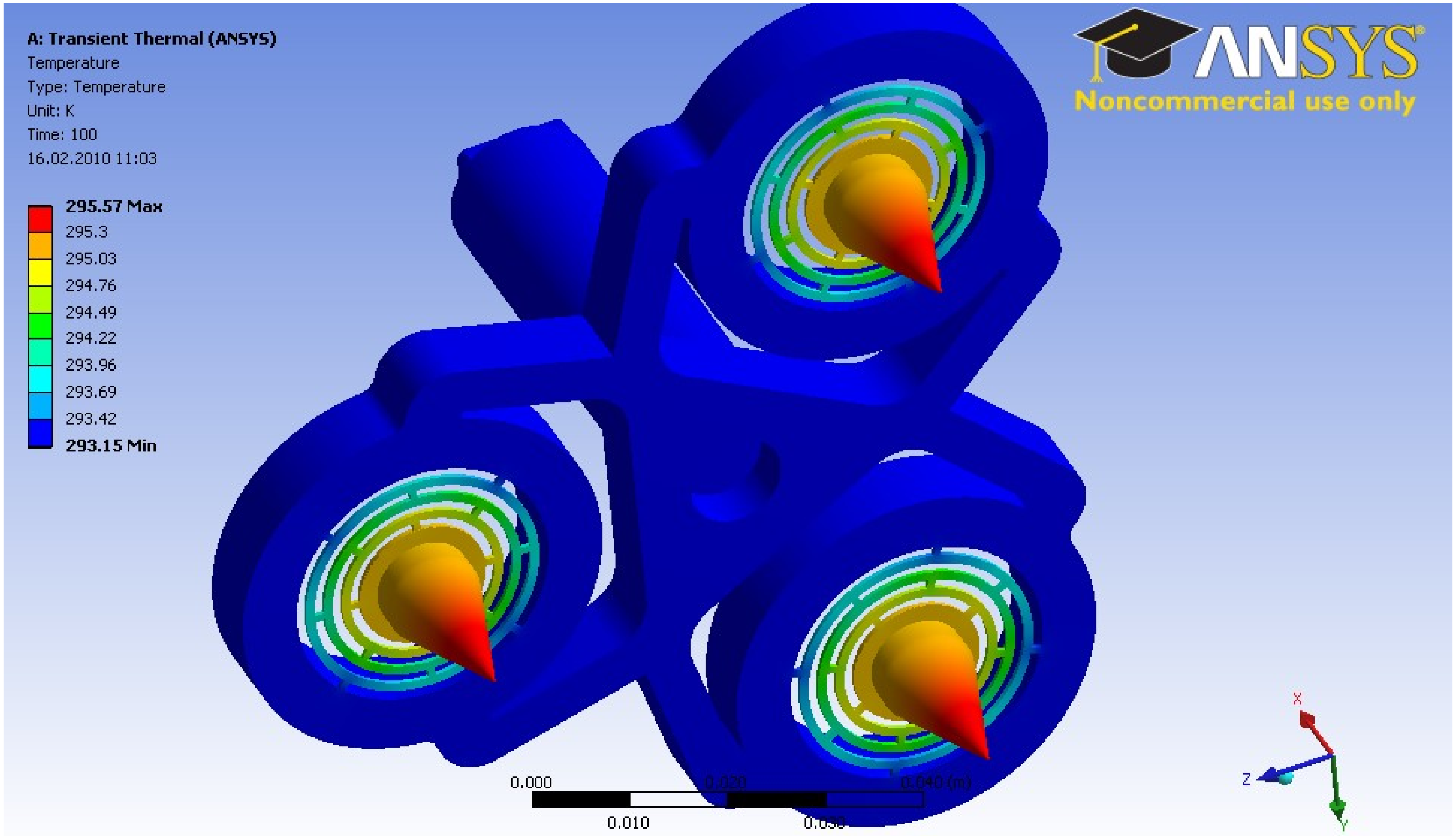


Brun et al., 2010

PMO6/PREMOS Thermal Stability



New TSI Radiometer



Highly symmetrical design for improved thermal stability and control of heat flows

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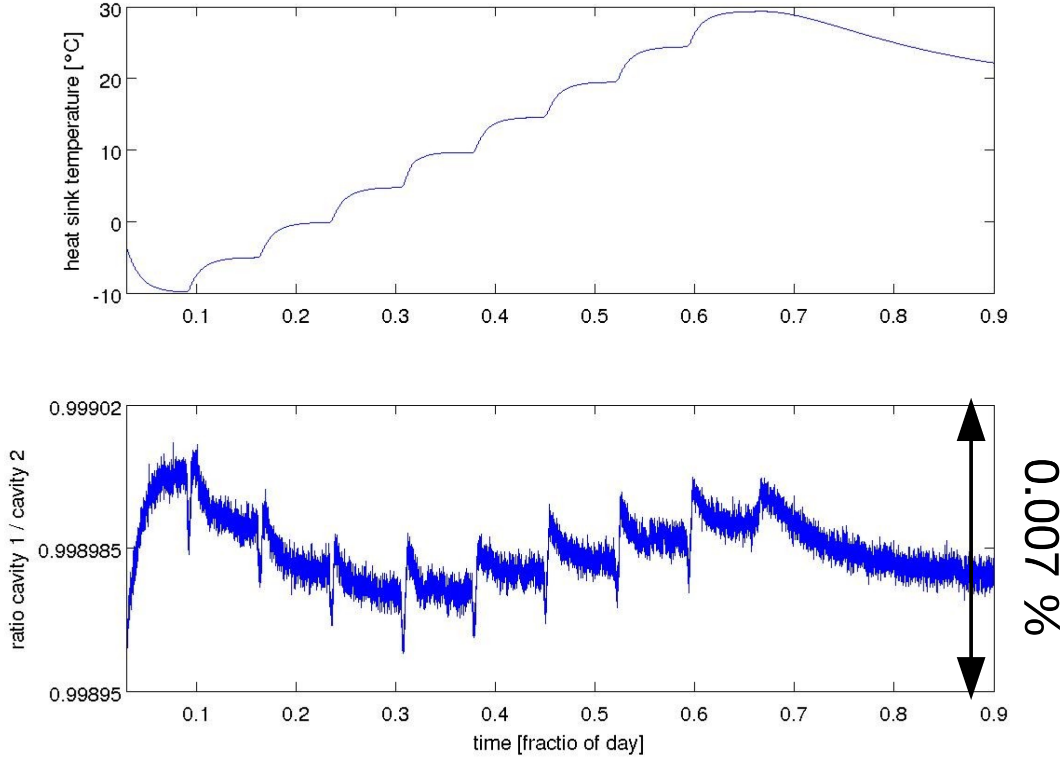
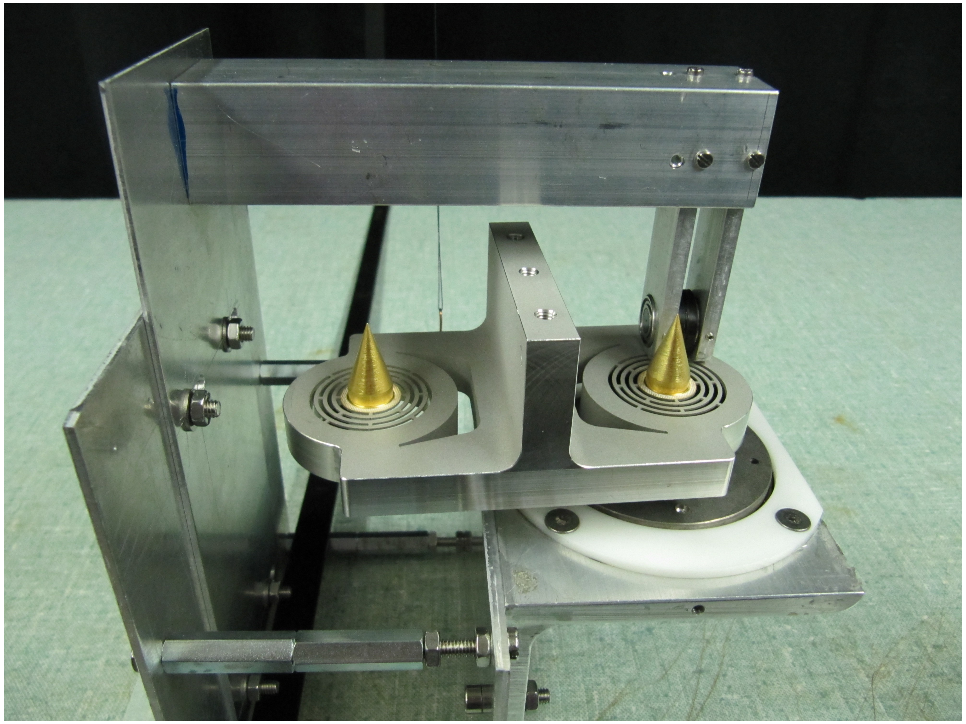
Thermal Stability (-10 – 30 °C)





Reproducibility of measurements better than 10 ppm

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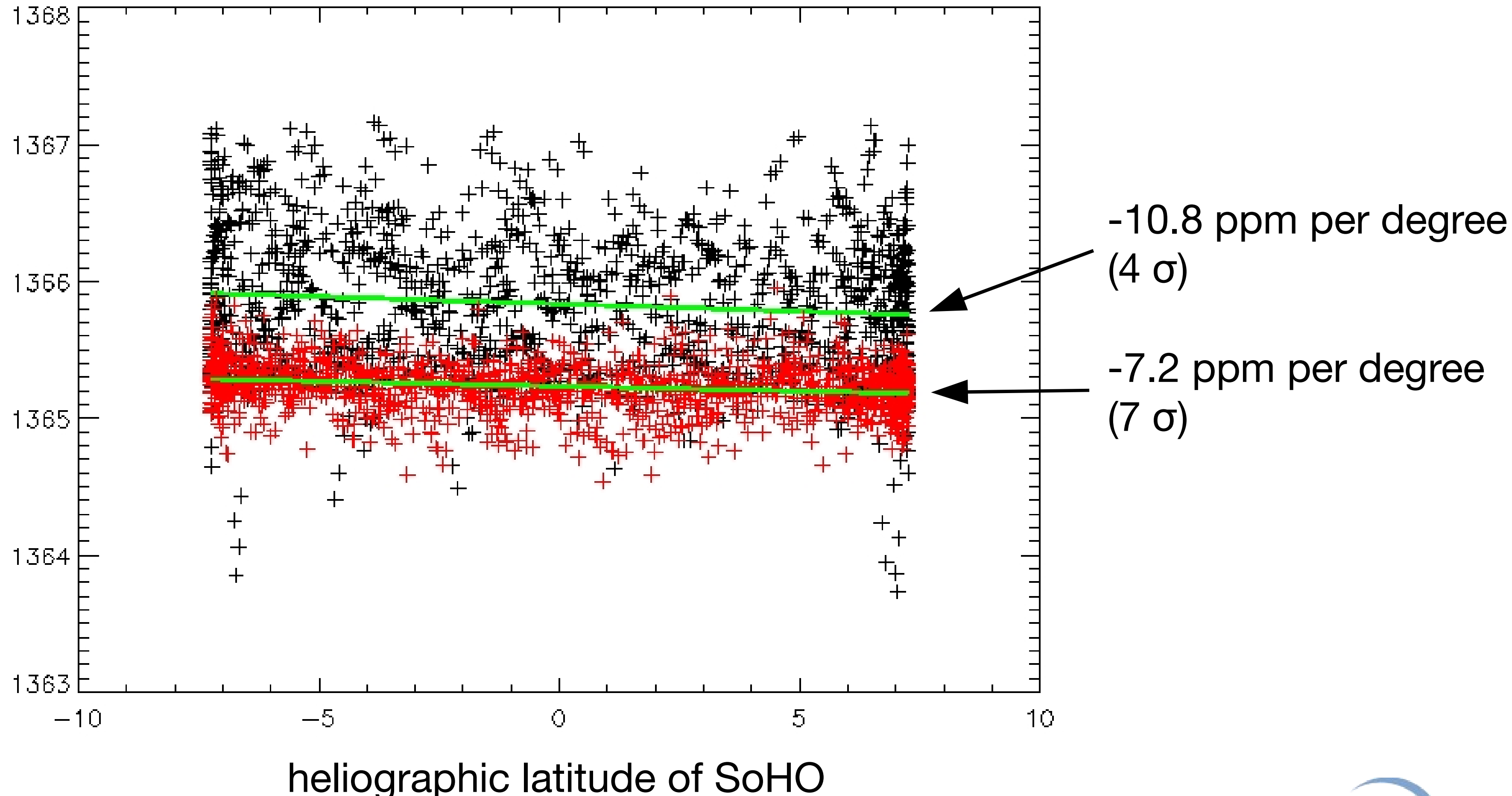
What do we expect to see?

VIRGO Irradiance with Krivova Model subtracted (Krivova et al., 2003)



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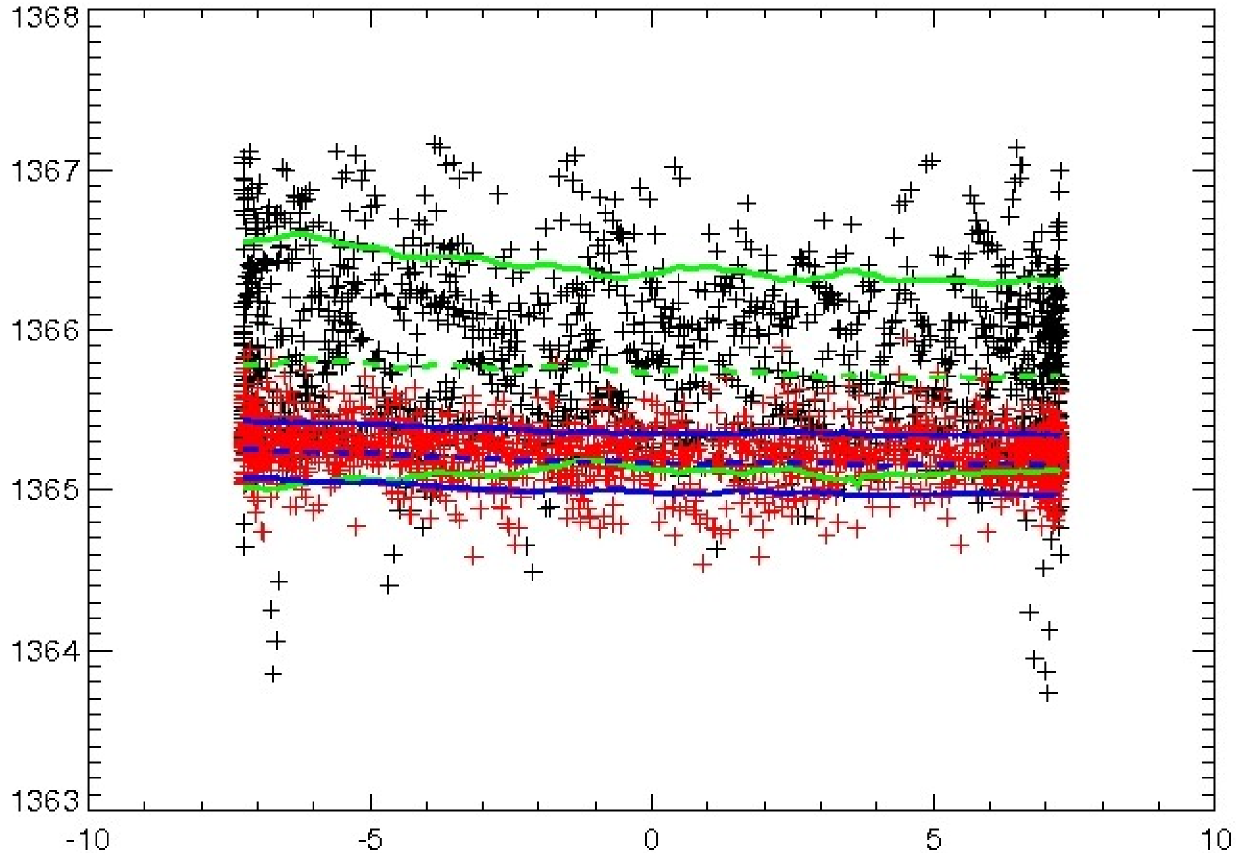
N-S Asymmetry in Variability

Irradiance Variability



heliographic latitude of SoHO

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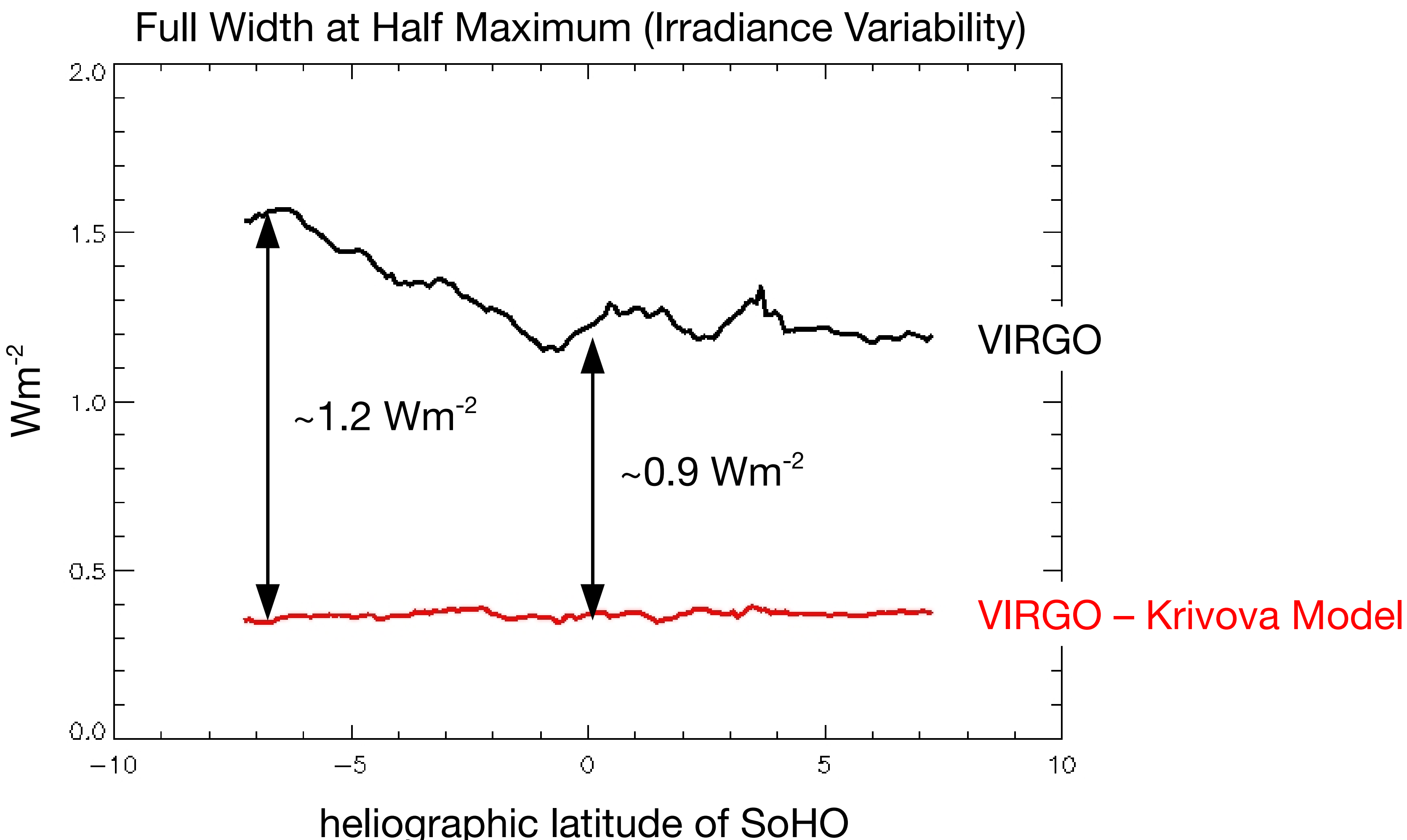
Results from VIRGO/SOHO



“The influence of an inclined rotation axis on solar irradiance variations”

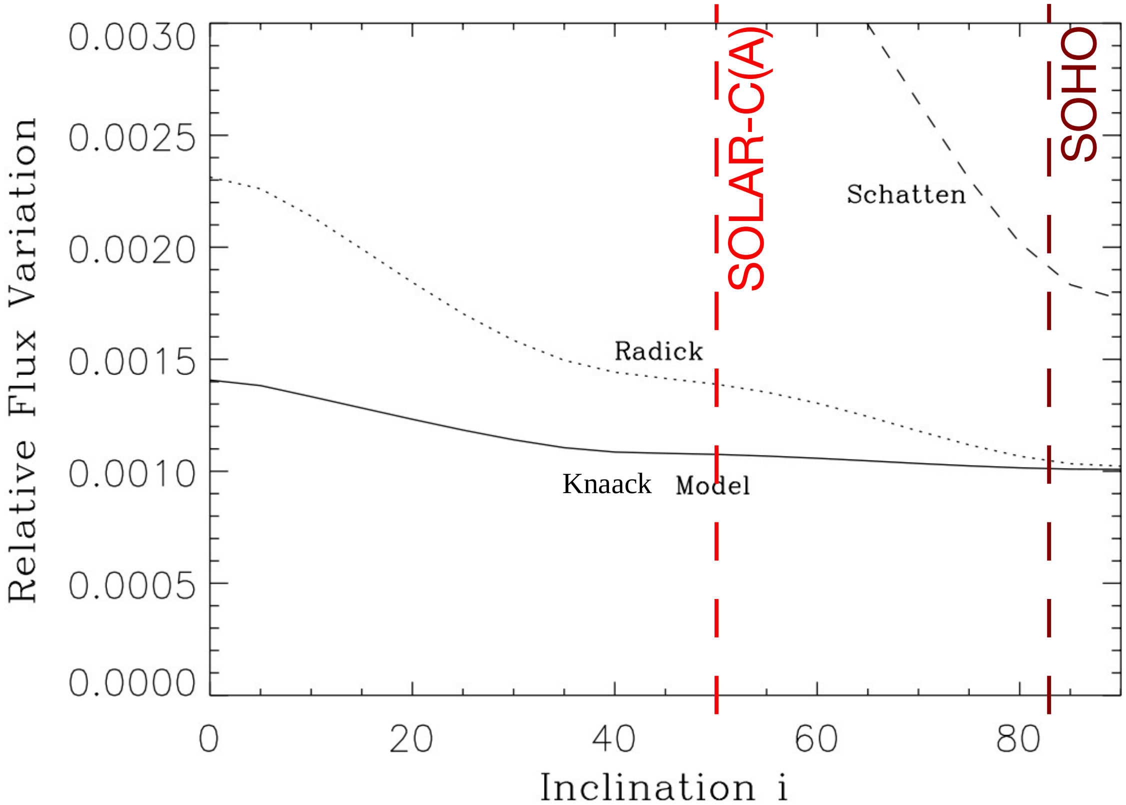


Fig. 10. Comparison of the inclination effect for the flux integrated over the total wavelength range predicted by our model and under the assumptions of R98 and S93.

Knaack et al. 2001

Summary of VIRGO Results

- Ascending phase of solar cycle 23 appeared to be asymmetric
  - Larger *variability* on the southern hemisphere
  - Fully explained by Krivova TSI reconstruction
  - High-latitude observations allow to discrimination between conflicting model predictions
  - Accurate measurement of N-S asymmetry may help to better understand the solar dynamo

Summary of Scientific Return from TSI on SOLAR-C(A)

- Solar Luminosity
  - Temperature of solar core and surface
    - Energy production rate
    - Differential rotation, meridional circulation
    - Re-calibrate standard solar model and stellar evolution theories
- Asymmetries in activity pattern
  - Discriminate between conflicting models
  - Confine dynamo governing parameters