How Bright is the Sun?
How Round is the Sun?

H. S. Hudson
Space Sciences Laboratory
University of California, Berkeley
and University of Glasgow

- *The most prosaic kinds of astrophysics?*
- *But with new, exciting, and relevant developments*
- *(if time) The Megamovie*

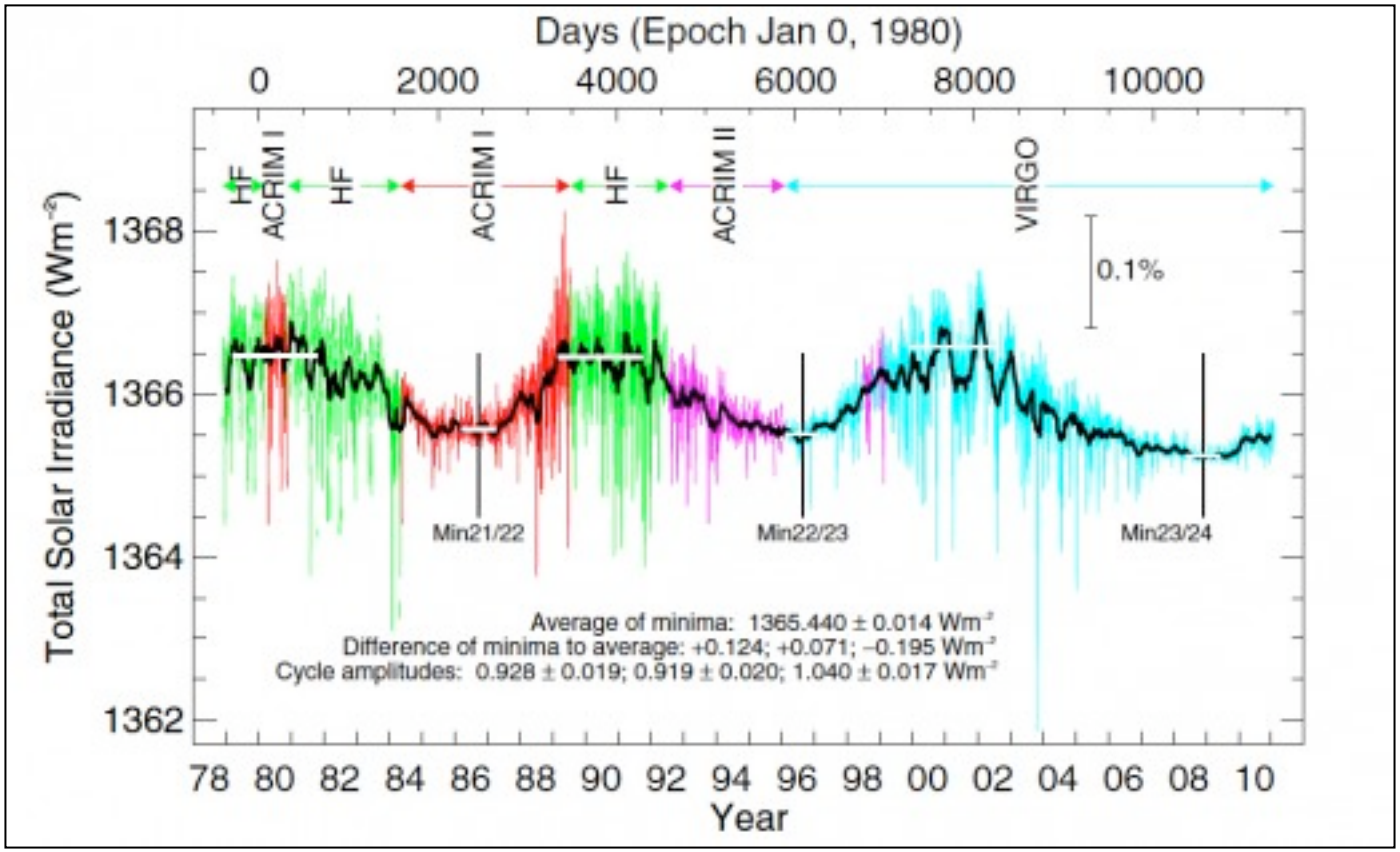
Basic motivation

- The mass, radius, and luminosity of the Sun are the basic yardsticks by which we measure the Universe:

$$M_\odot, R_\odot, L_\odot$$

- These are already large quantities, beyond our terrestrial experience, and relate to a far-away body that we cannot do experiments on
- Modern precise measurements are showing inexplicable fluctuations

The “Solar Constant”



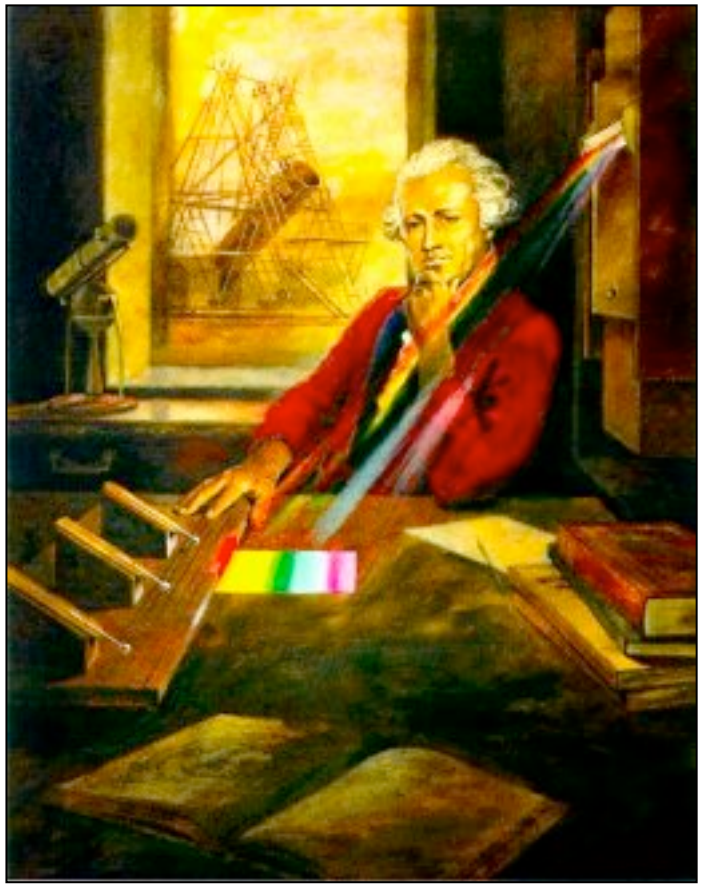
How bright is the Sun?

- This question is somewhat ambiguous:

  - $L_{\odot}$ measures the total energy output of the Sun

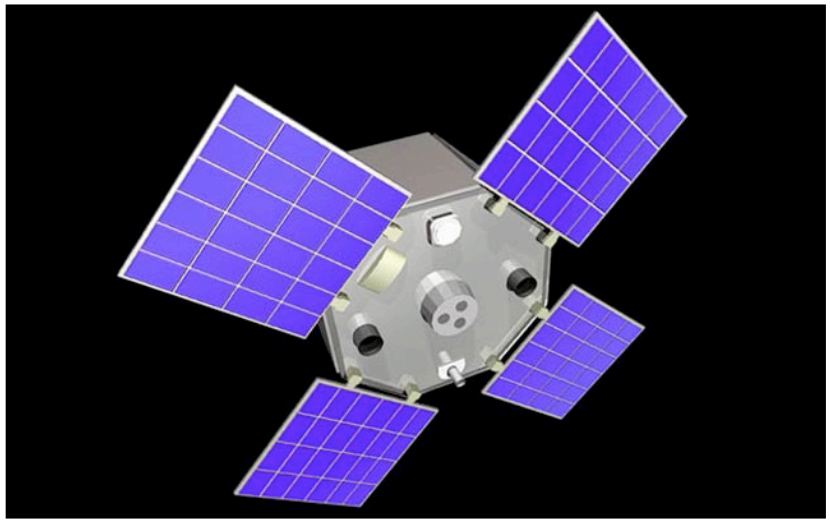
  - The “solar constant” measures the radiant energy incident on the Earth: TSI (a TLA)
- Solar radiation is not isotropic!
- The Earth’s orbit is not round!
- Radiometric measurements are difficult!

The “Solar Constant” measurement

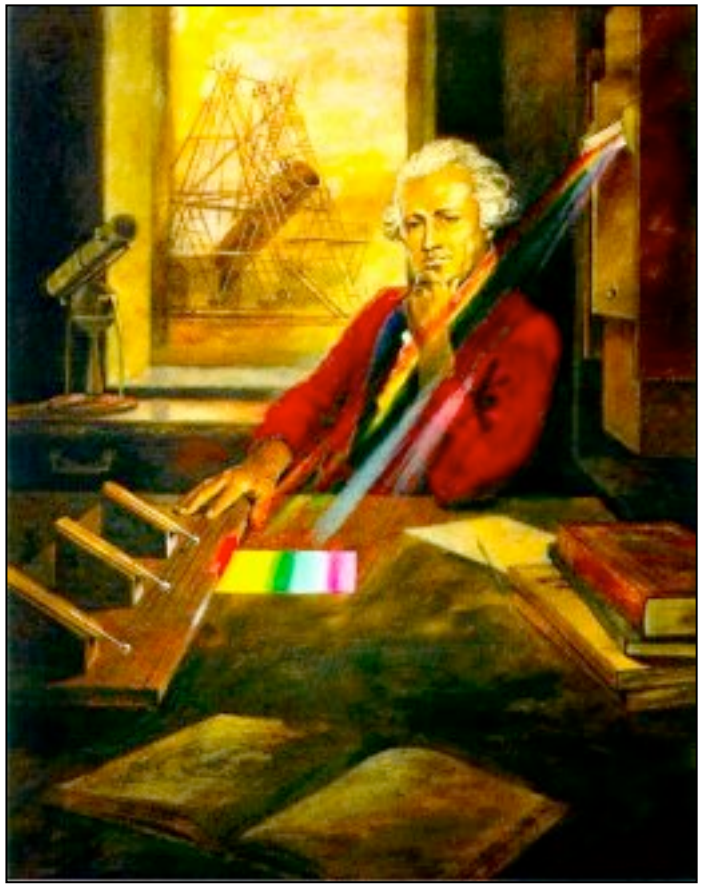


Herschel

ACRIMSAT



The “Solar Constant” measurement



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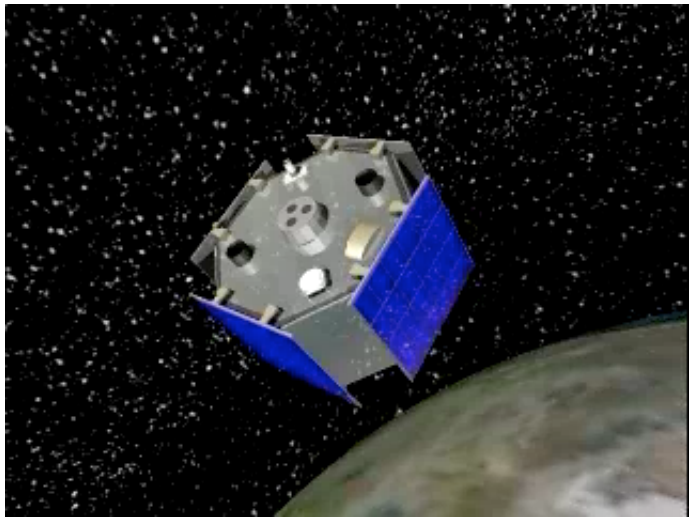
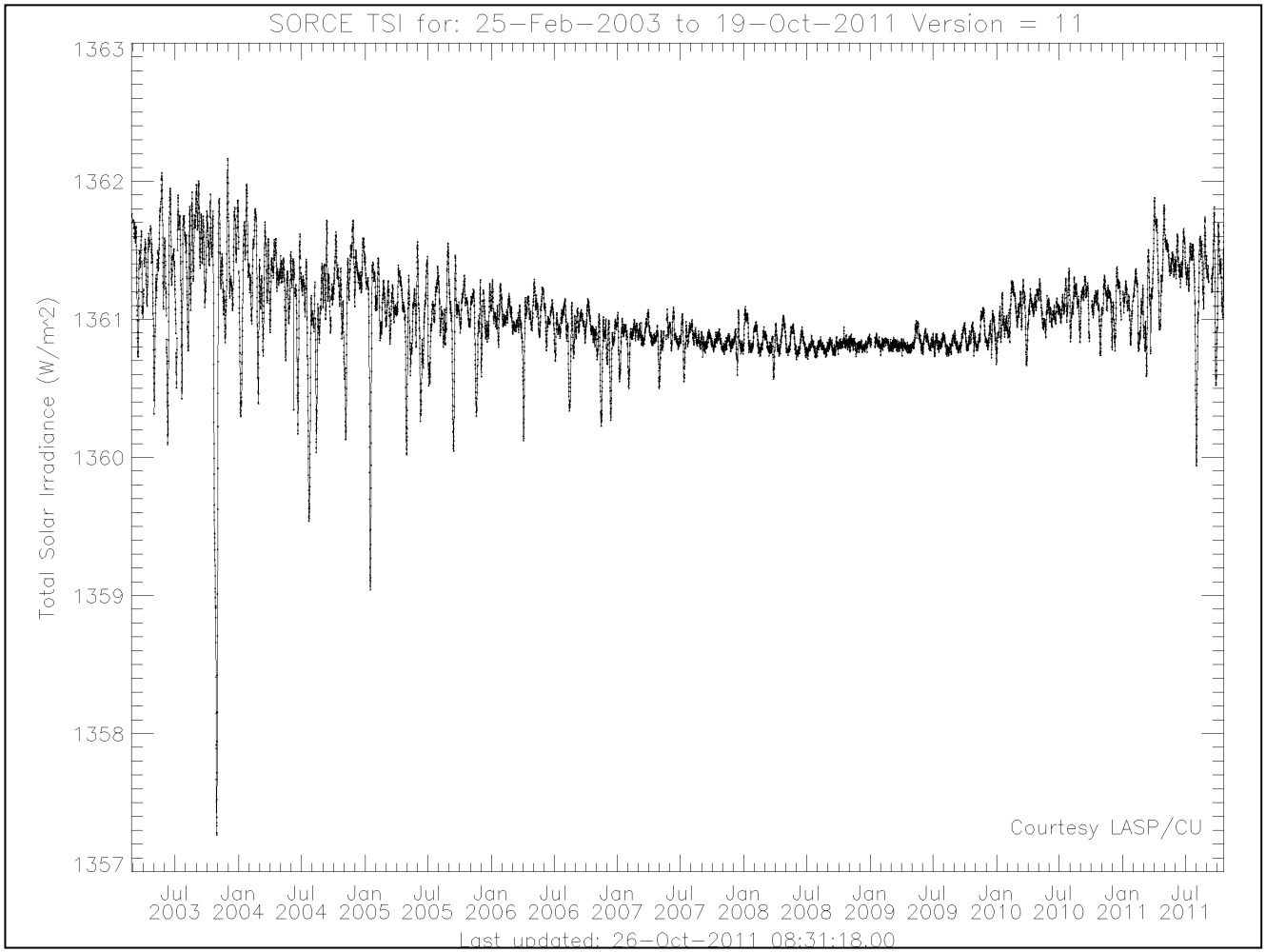


Current Measurements



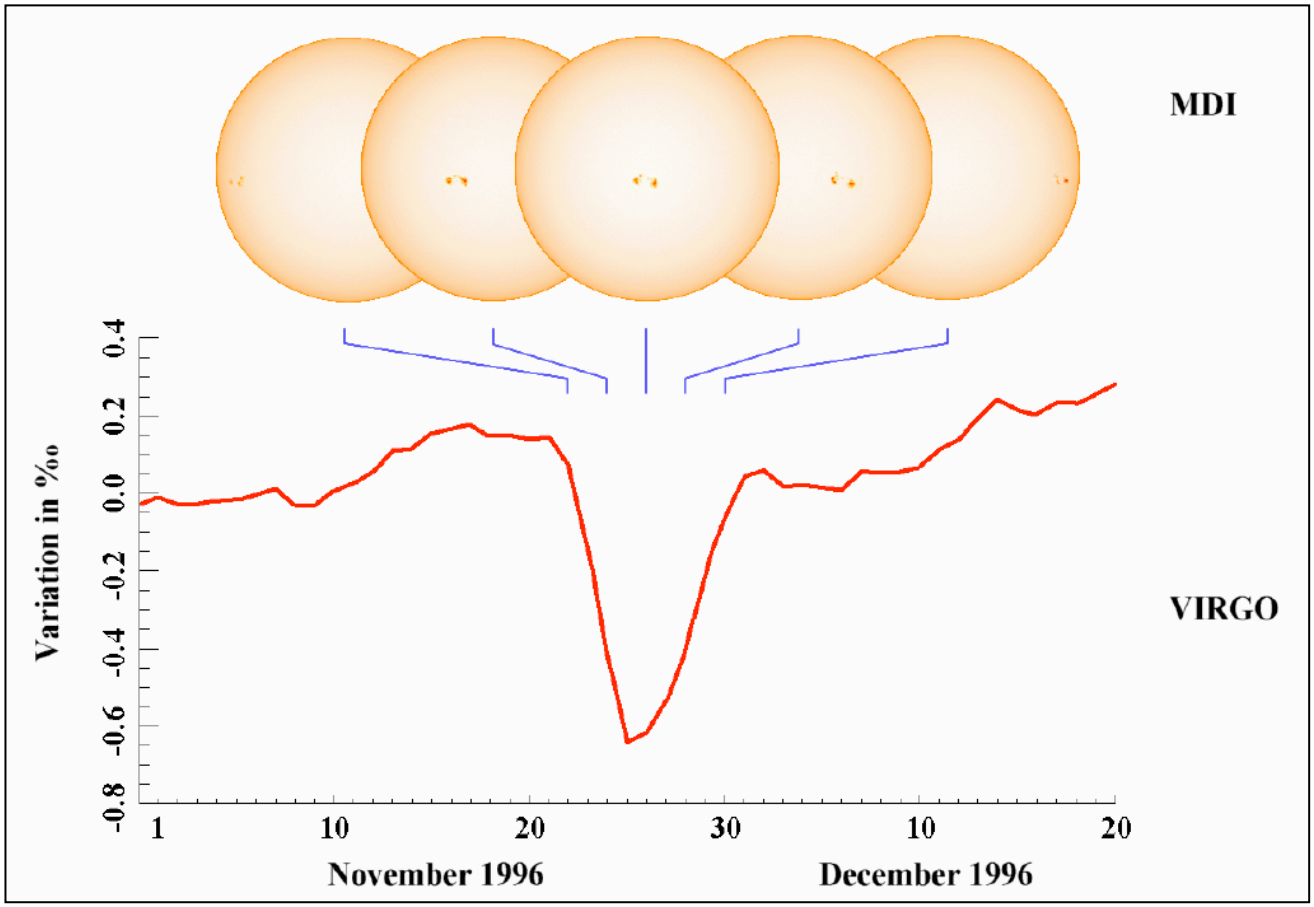
July 2003

July 2011

SORCE

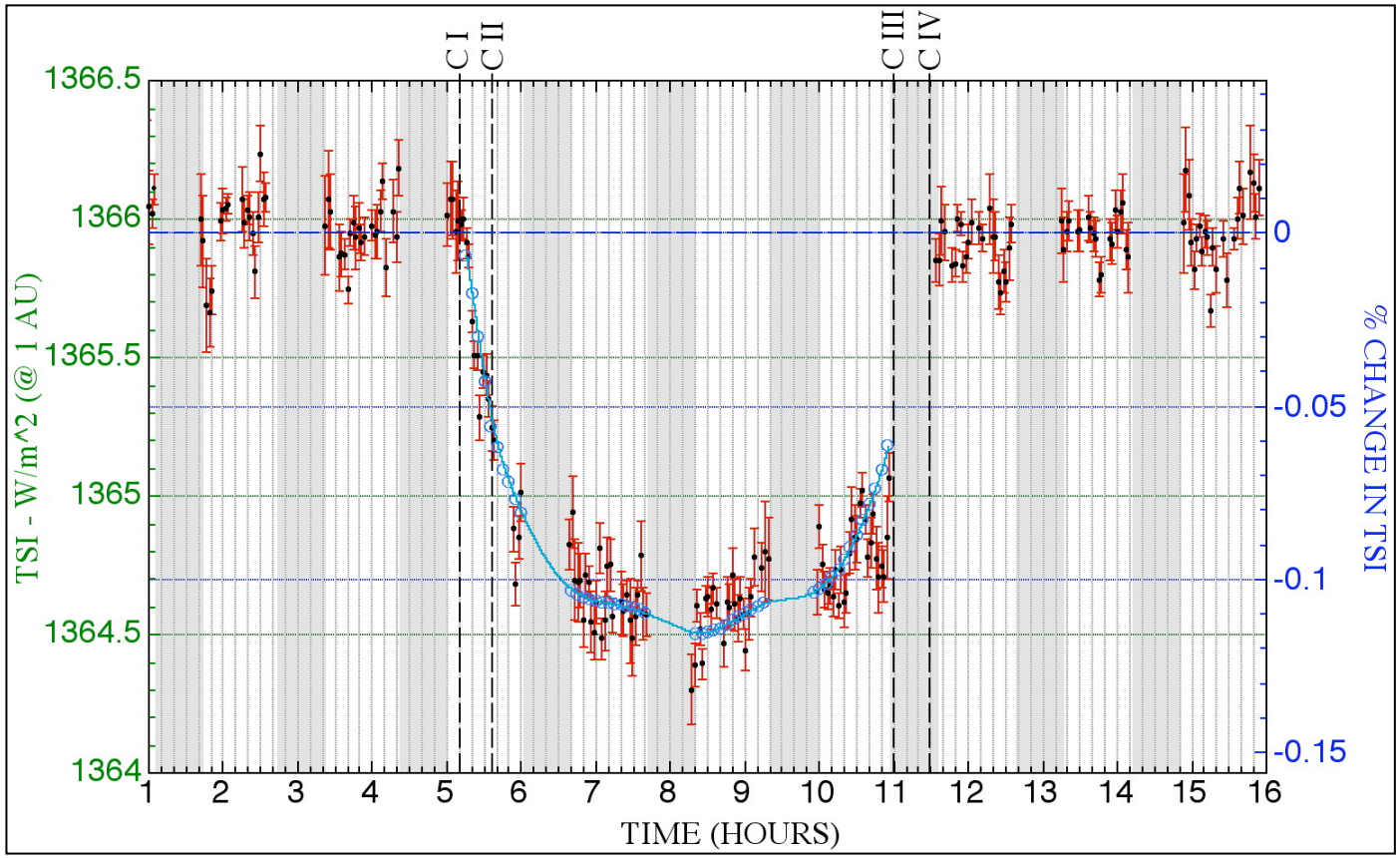
Mills Observatory, 28 October 2011

A Sunspot



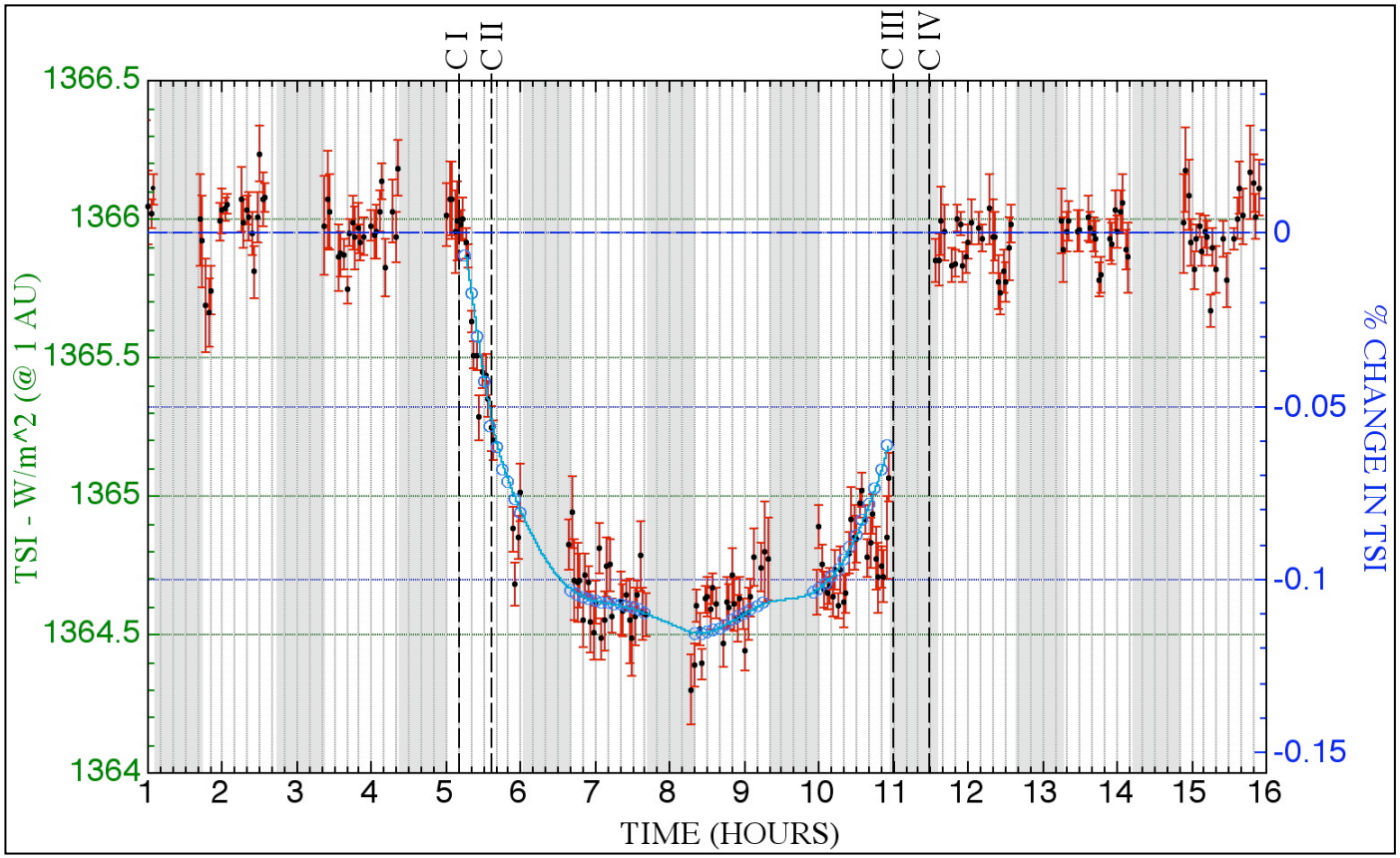
N. Krivova

A TSI Transit of Venus



Pasachoff, 2005

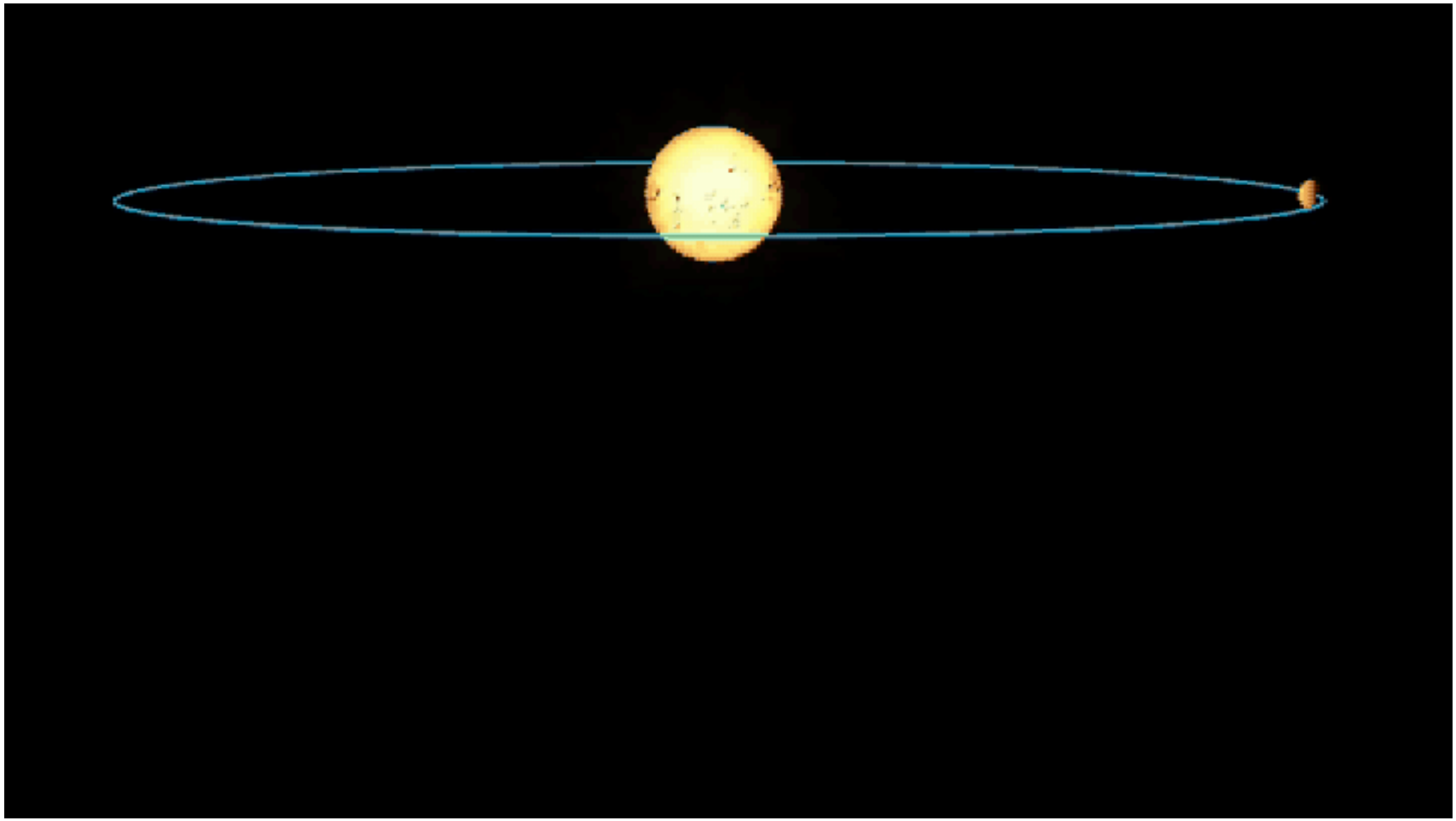
A TSI Transit of Venus



Pasachoff, 2005

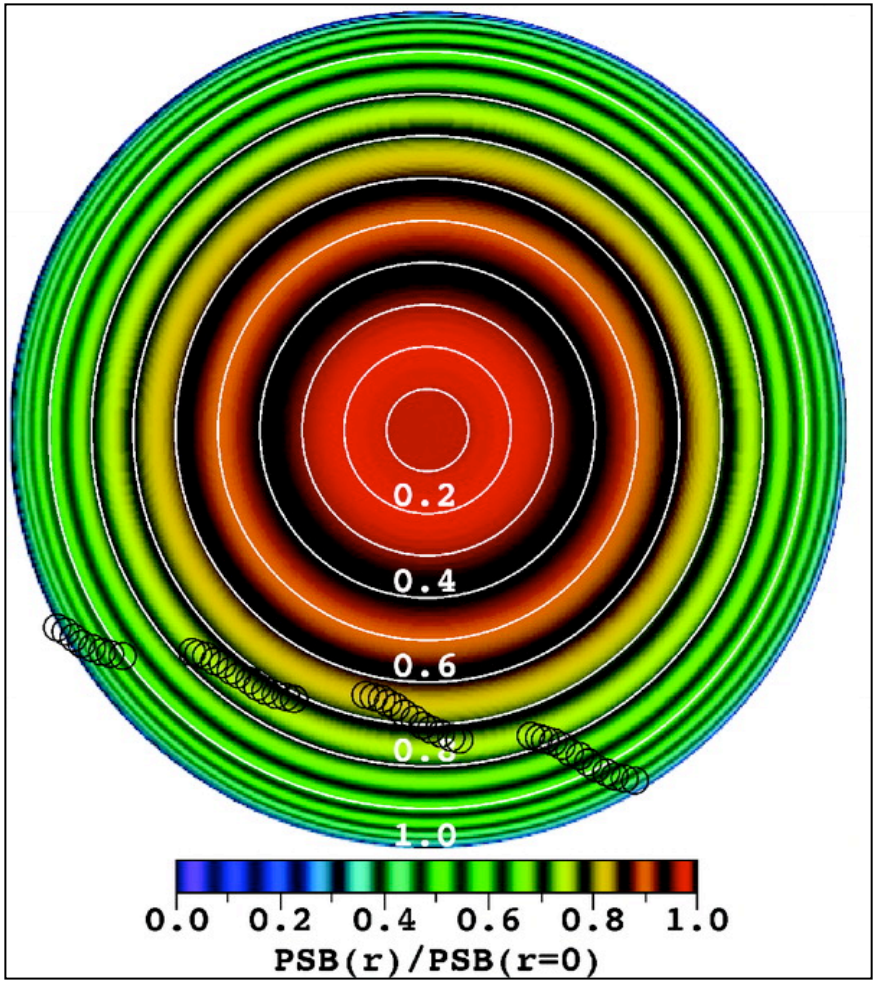
p.s. 2012 June 5-6, 22:09-04:49 UT – our last chance!

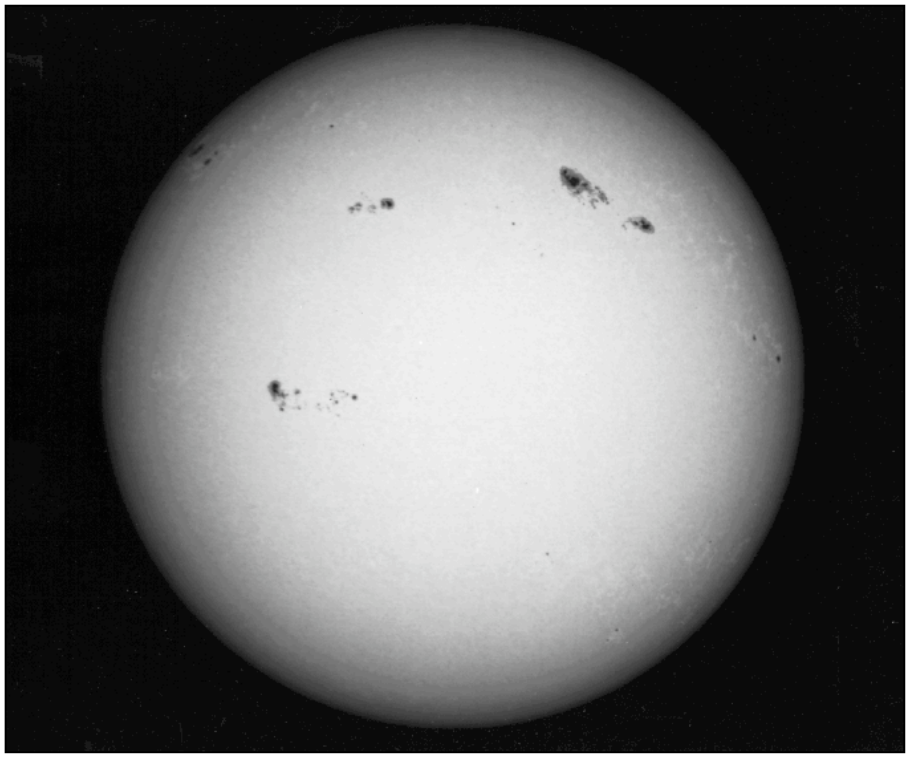
An aside: Planet Search



The *Kepler* planet-finder

Limb Darkening



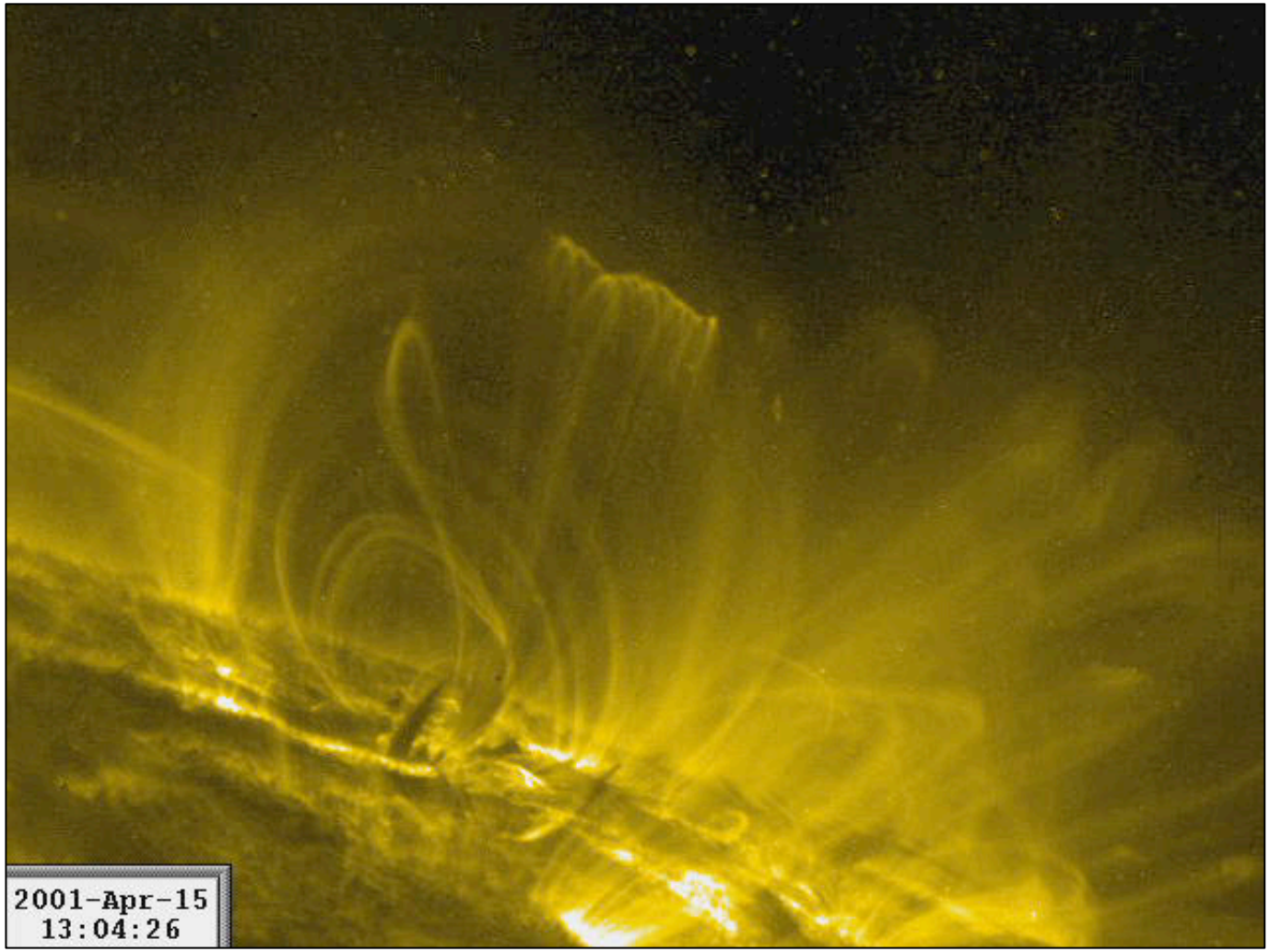


J. Pasachoff

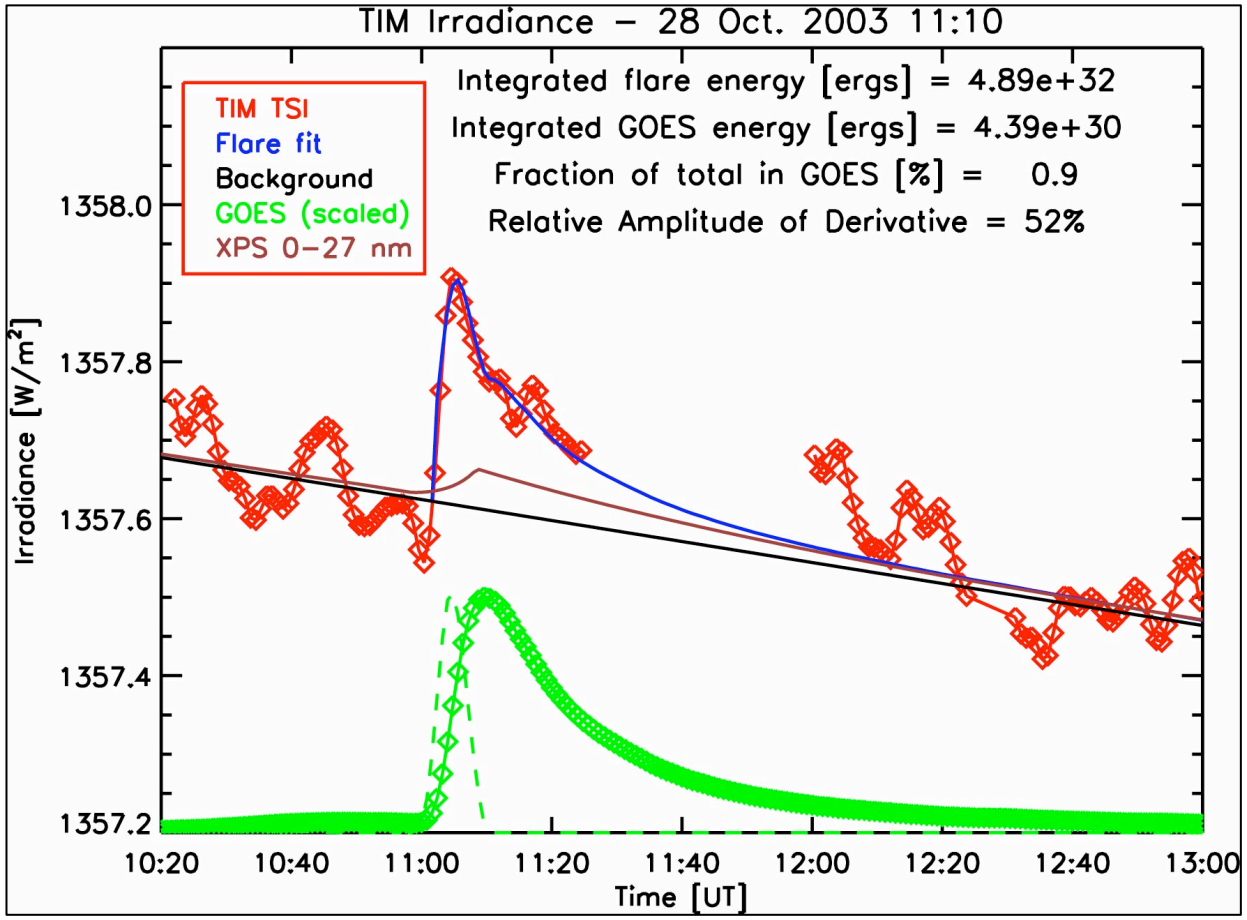
How bright is the Sun?

- There are many ways in which the Sun differs from a simple ideal uniformly bright sphere
  - There is limb darkening
  - There are blemishes: spots, granulation, Venus
  - There are time variations
- Time variations could affect life on the Earth, so we are more than just curious
- Precise measurement would therefore be interesting

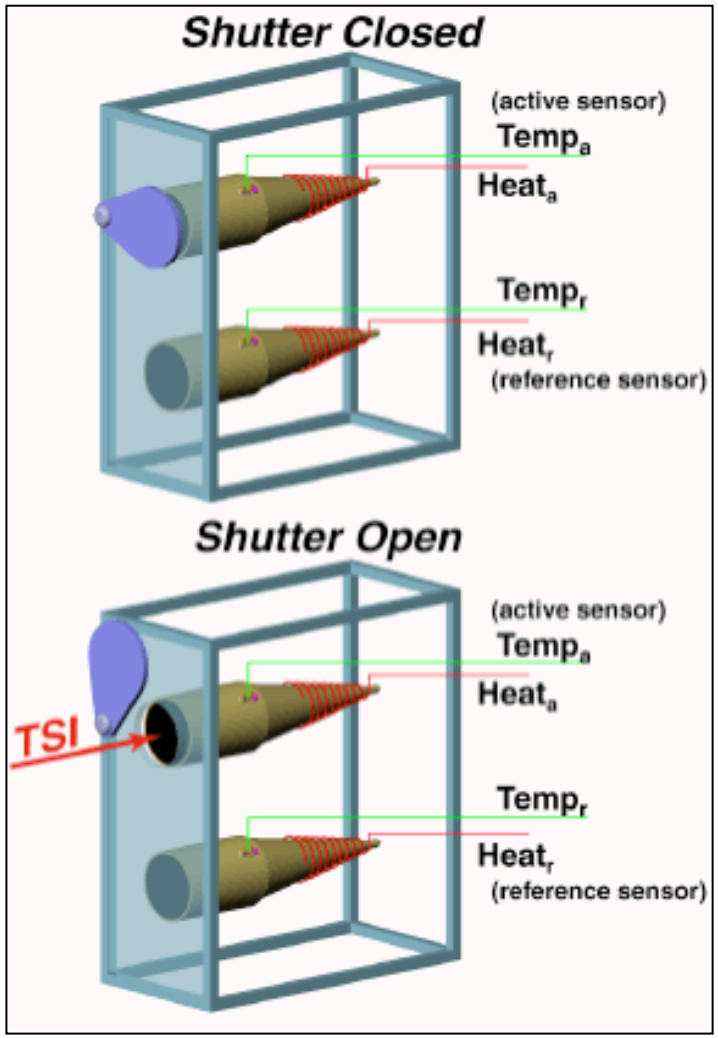
Solar variability: an extreme example

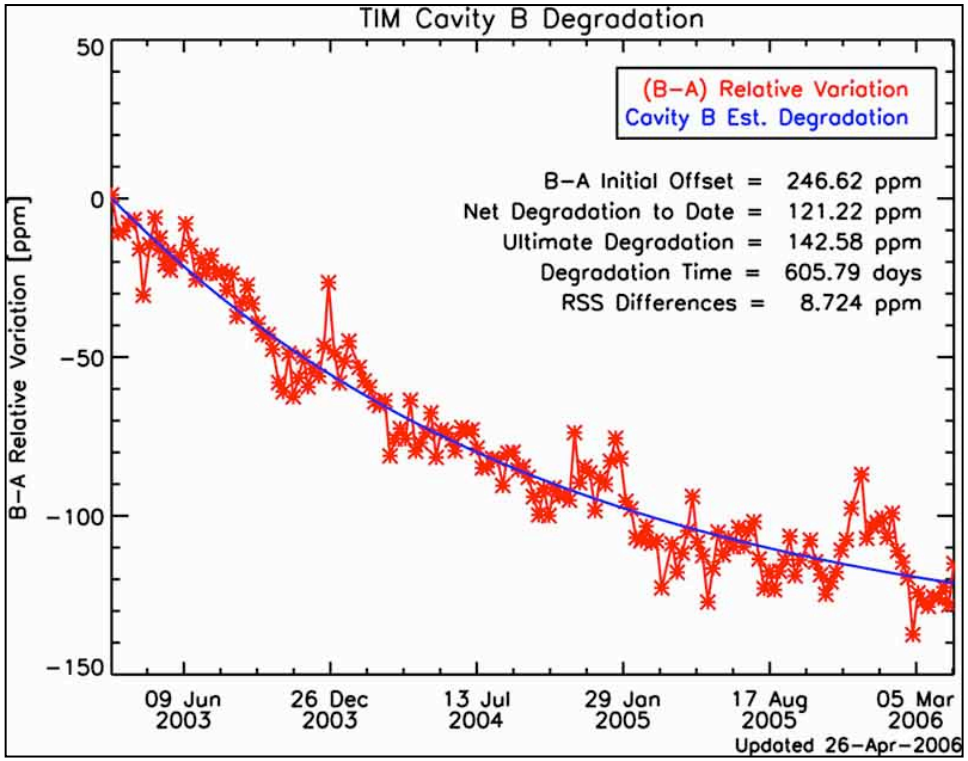


Today's Anniversary Flare



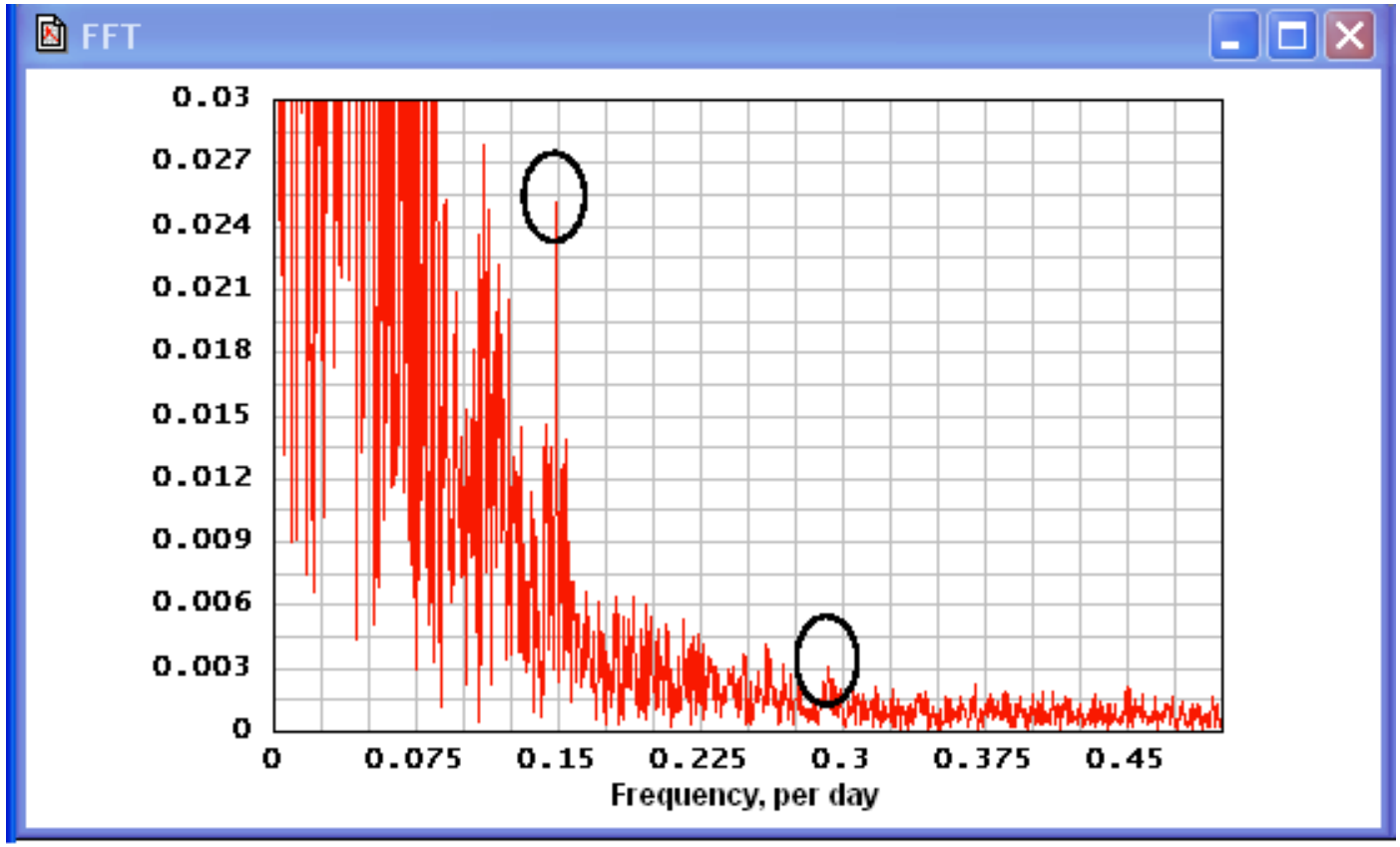
Differential measurements





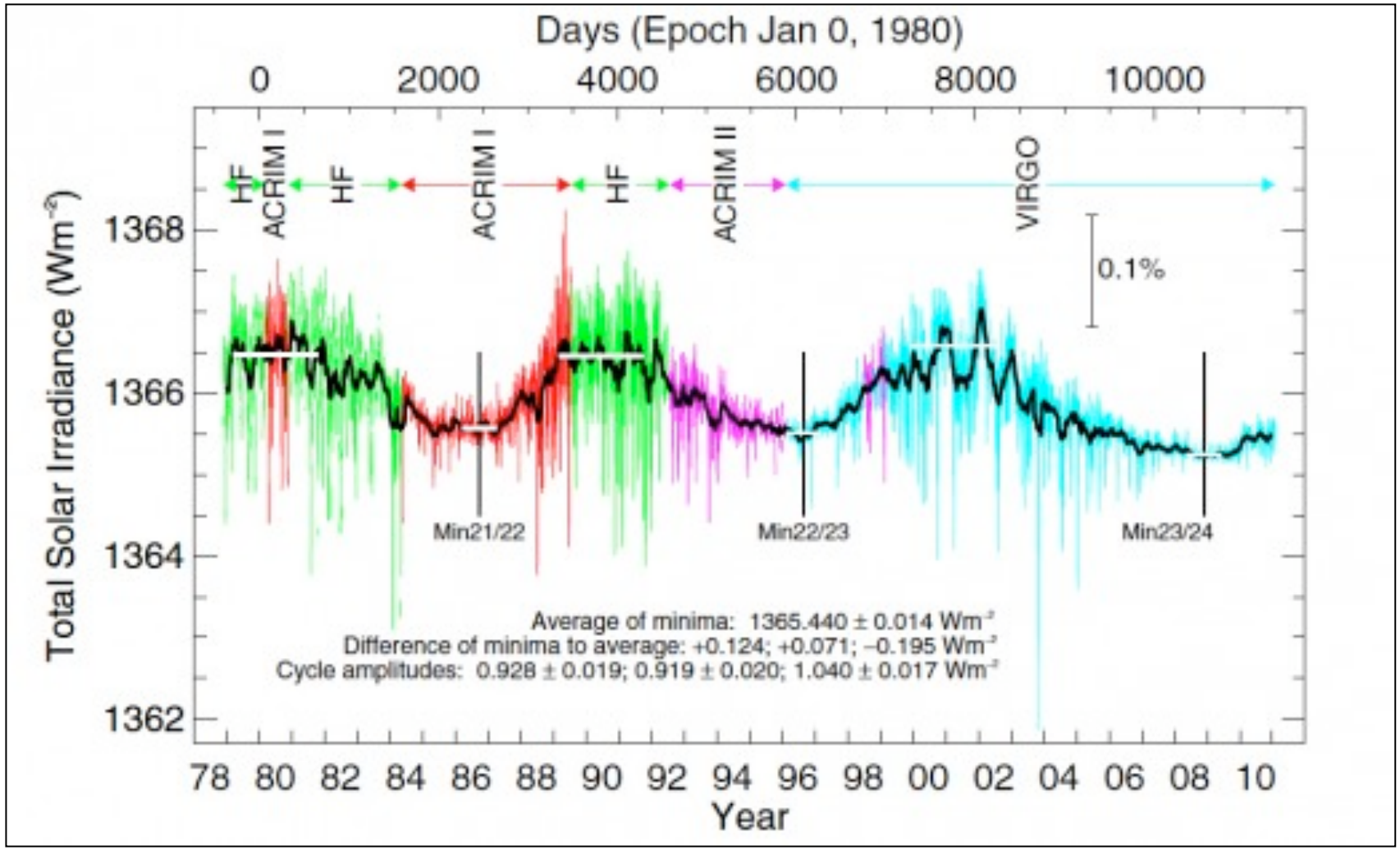
The Total Irradiance Monitor on SORCE (G. Kopp)

The “Friday Effect”



L. Svalgaard

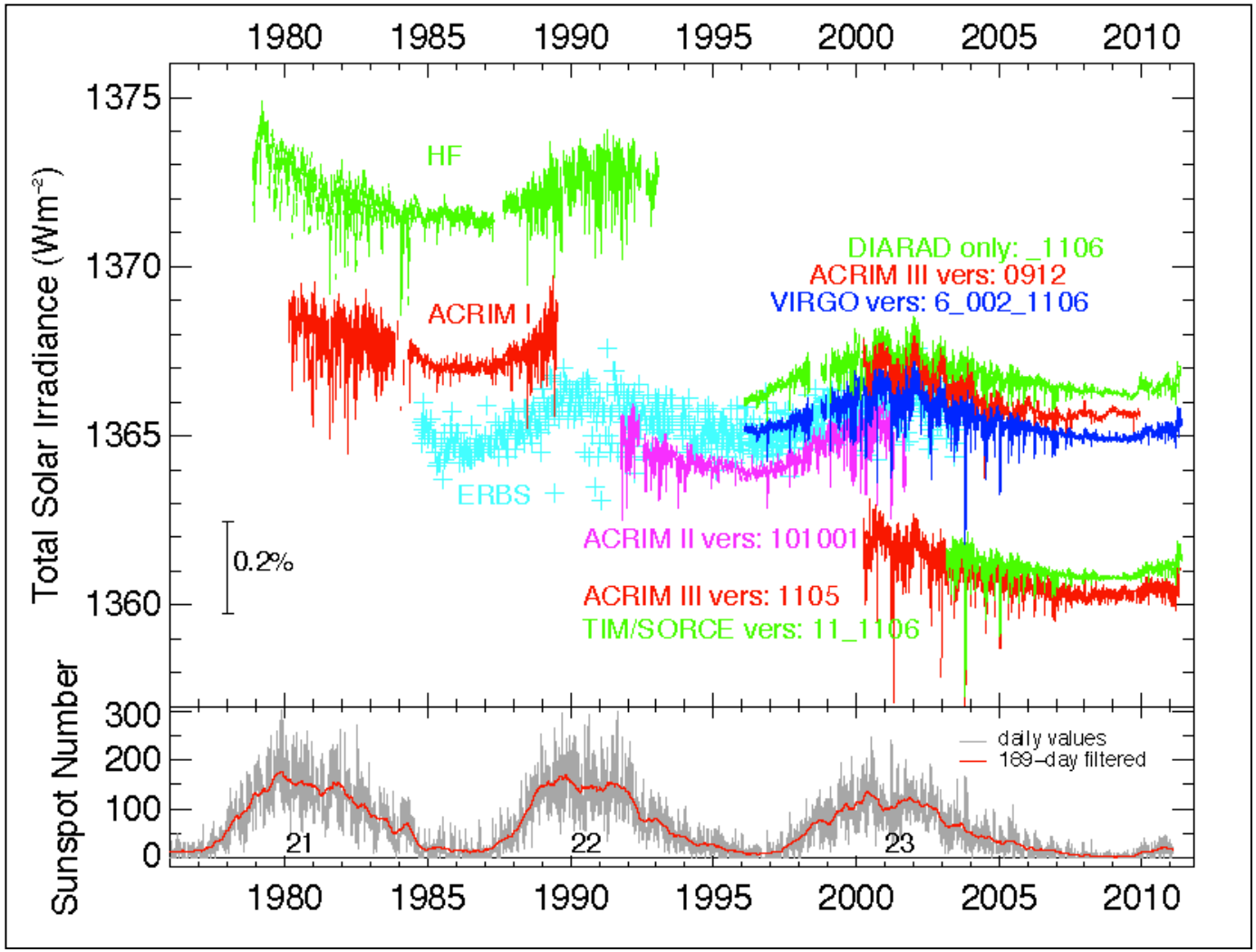
The solar constant (TSI) shows *slow* variations



What is the nature of the slow variations?

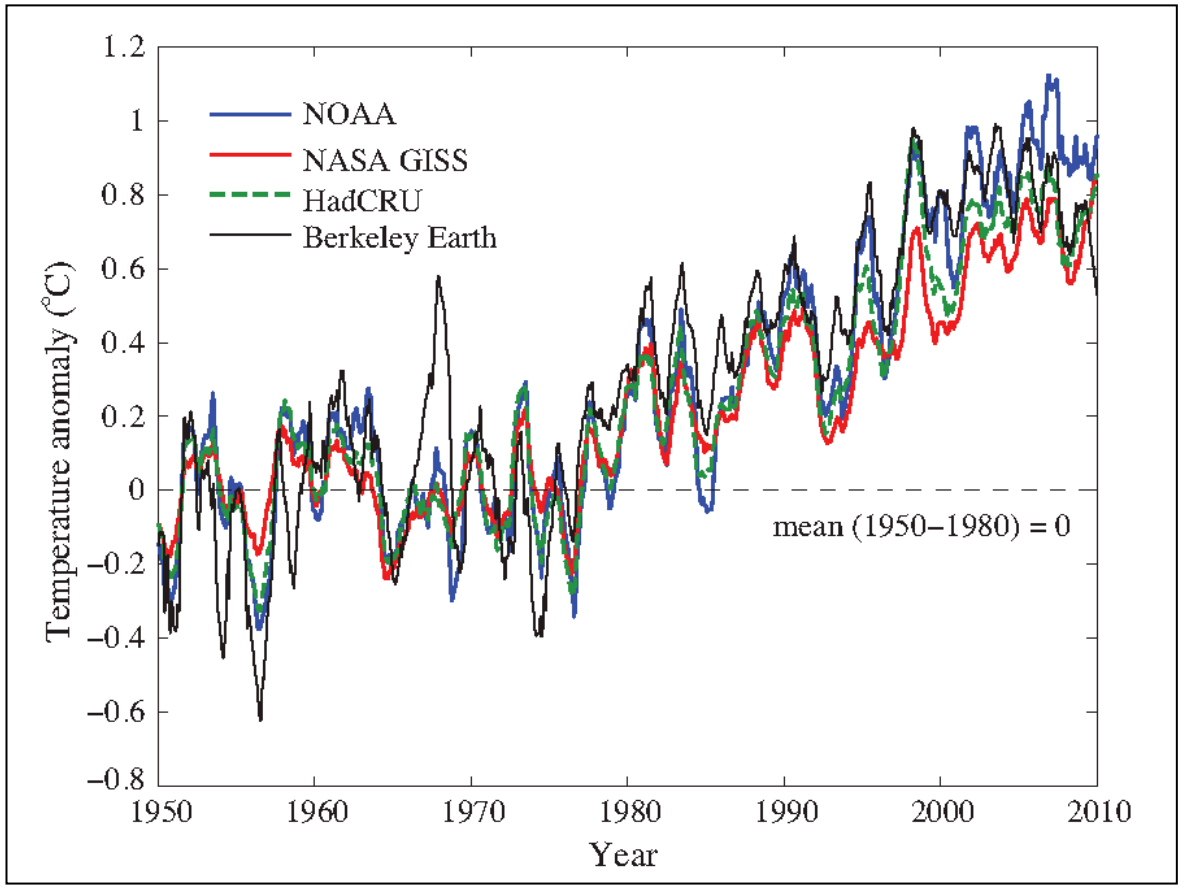
- The TSI variation between minima, just now observed for the first time, is about 0.3 W/m^2 per decade
- By astronomers' logic, this leads to a typical variation time scale of some 50,000 years.
- The "Kelvin-Helmholtz" time is ~20 million y.
- Something interesting could be happening even as we watch…

The full TSI measurement



Froehlich 2011

What does this have to do with global warming?

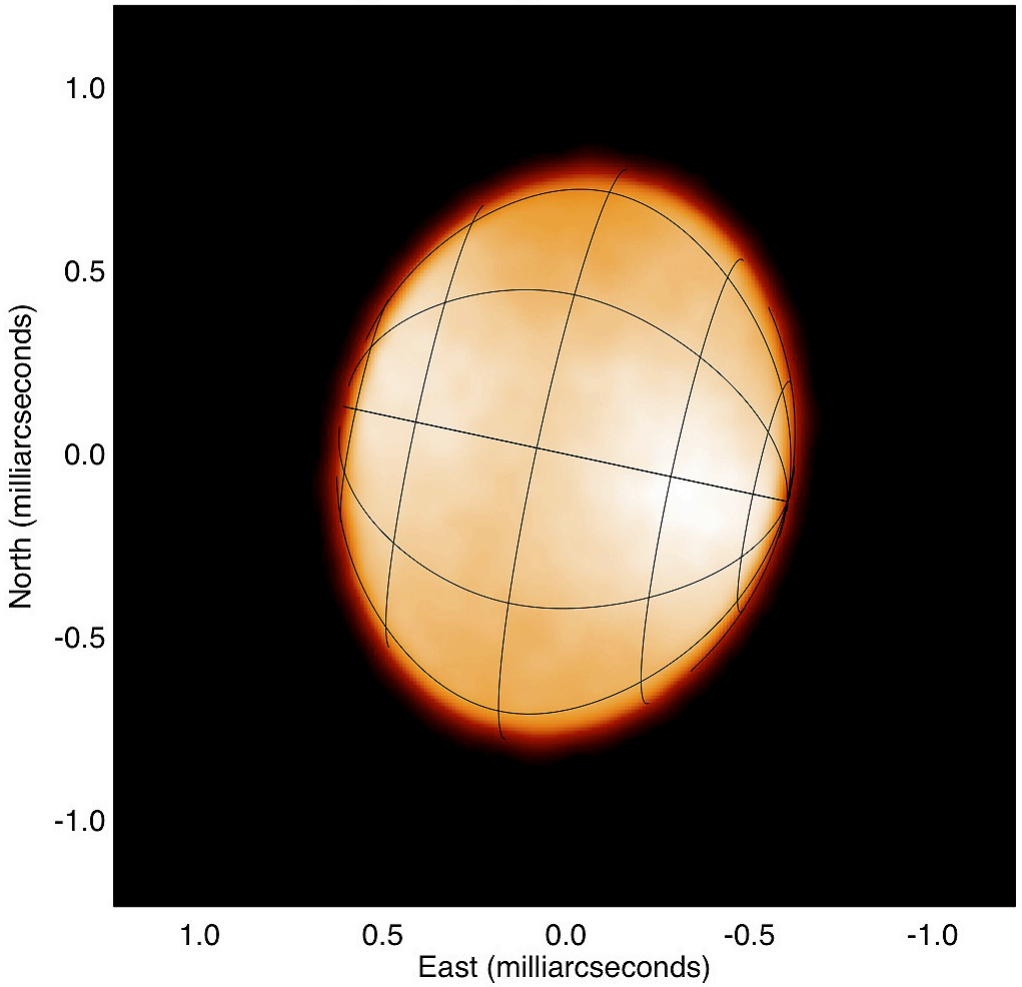


Muller et al. 2011

How Round is the Sun?

Sun with Shuttle and *Hubble*

Regulus Image Reconstruction



What does the Sun have to do with global warming?

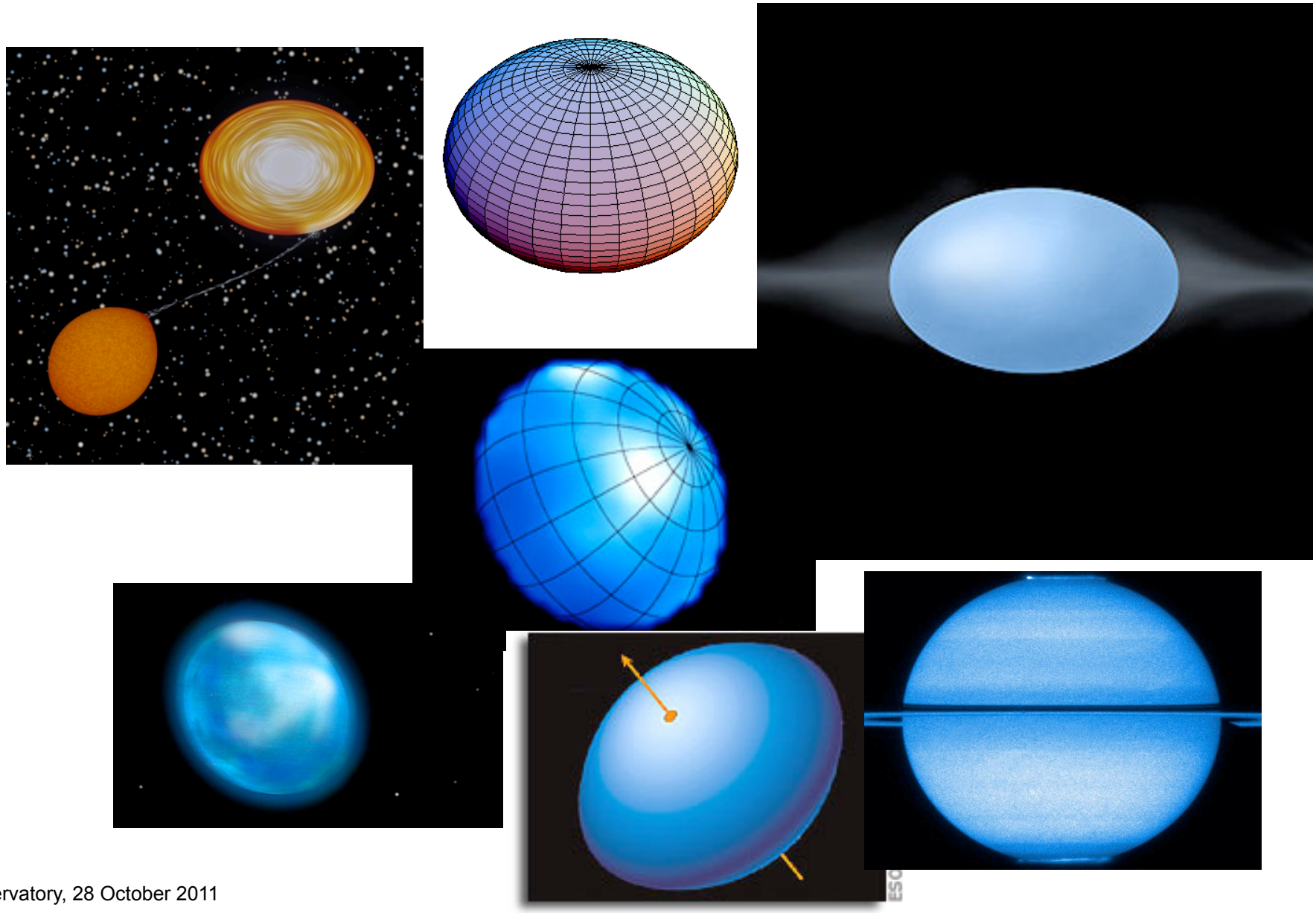
- Very little!

  - The new, precise TSI data do no show sufficiently large variations

  - The terrestrial temperatures don’t show a solar cycle

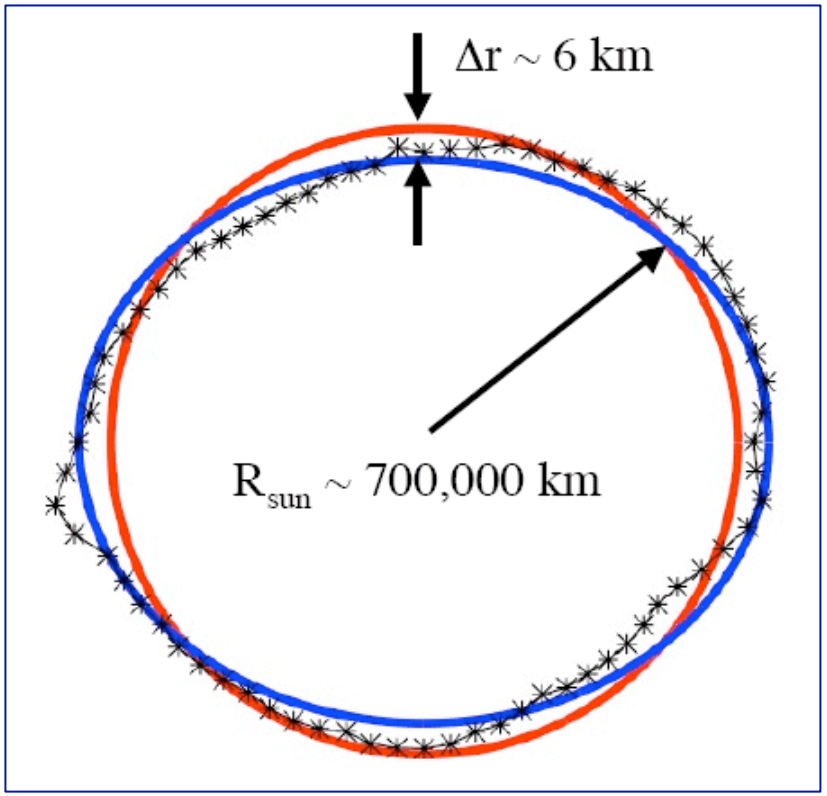
  - The terrestrial temperatures don’t show a slow change in the same sense as TSI

Really Oblate Stars

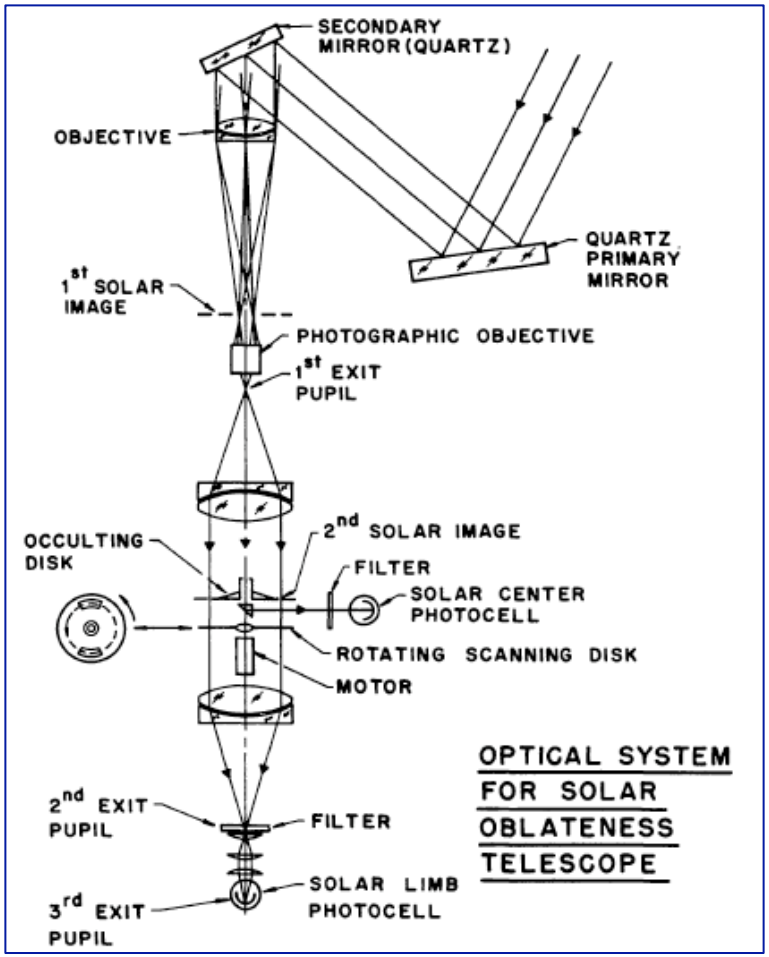


History of Solar Oblateness

- Rotation of Sun suggests a tiny oblateness: 10 ppm
- The actual value is important for understanding the 19th-century observation of Mercury's perihelion
- Robert H. Dicke (Princeton) initiated a new series of very precise measurements in the 1960s.

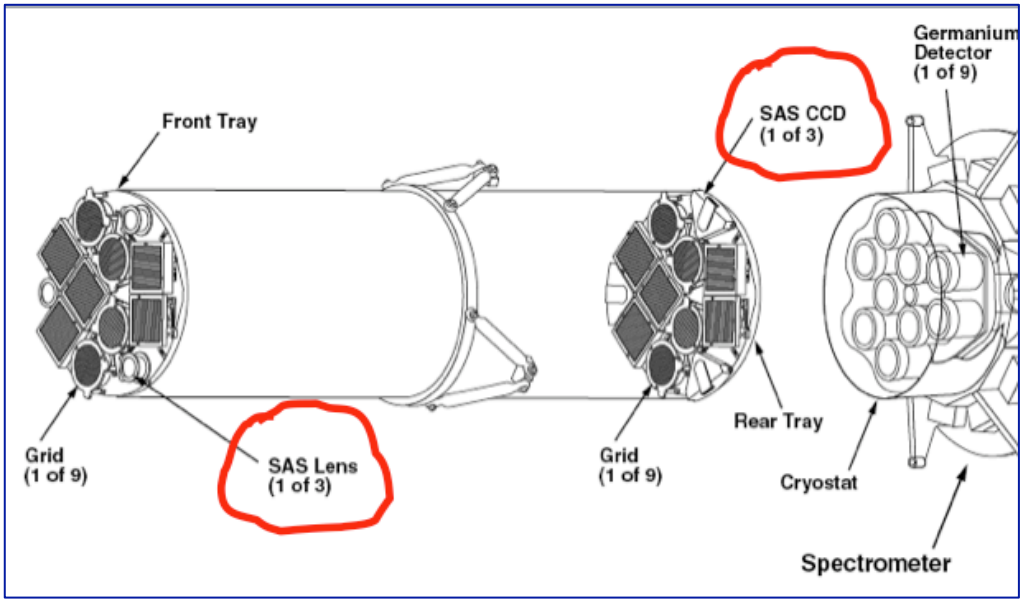


Special Telescopes for Solar Oblateness

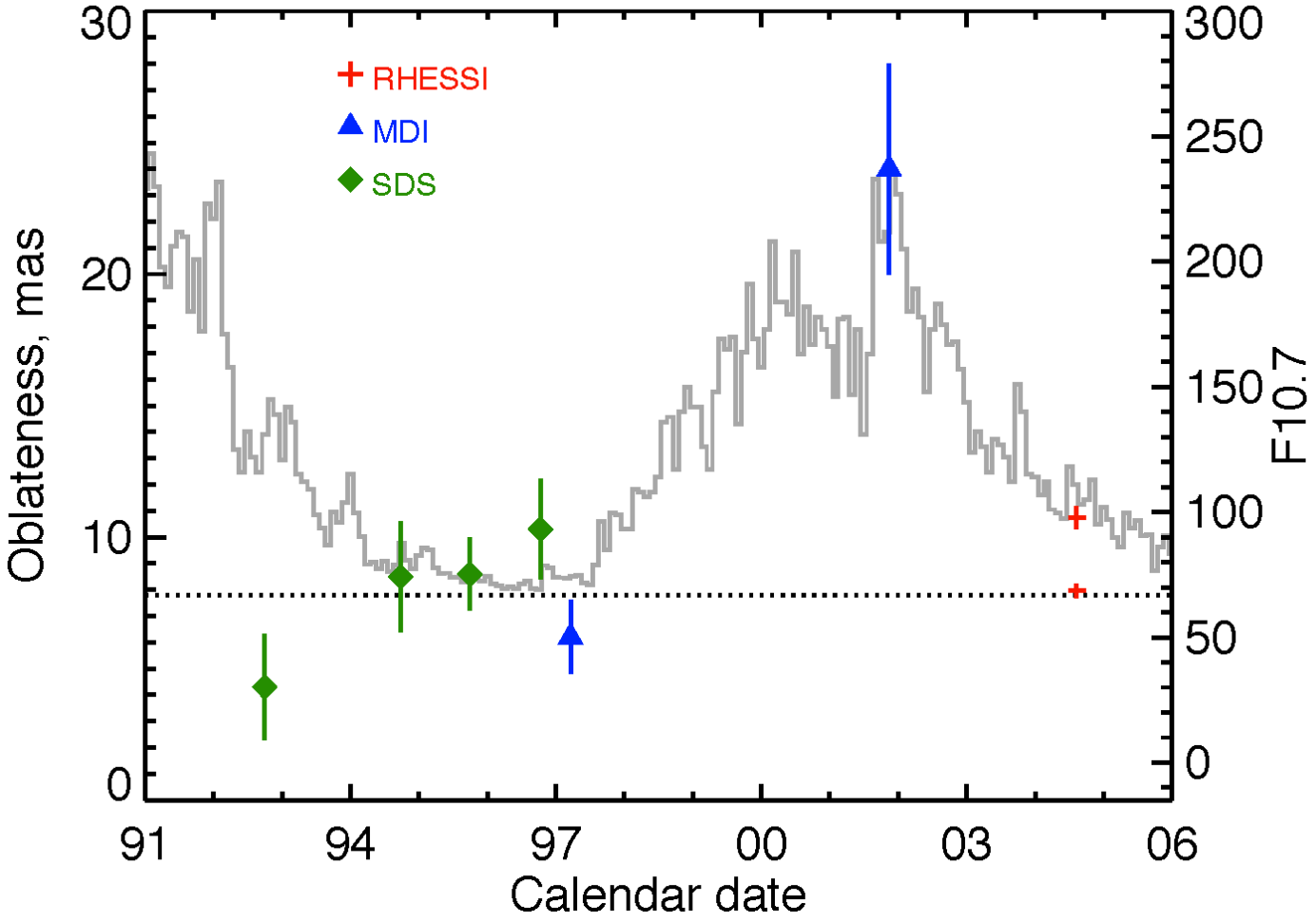


Princeton (Dicke & Goldenburg 1974)

Our satellite RHESSI

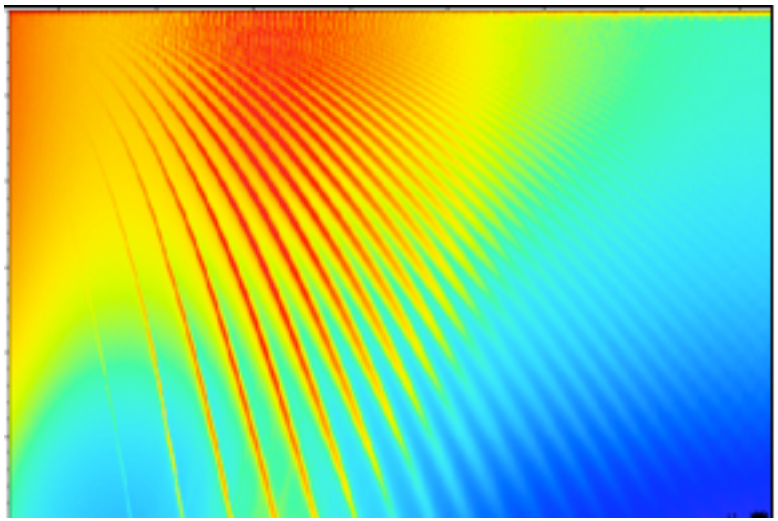


RHESSI oblateness result



What does the shape of the Sun have to do with global warming?

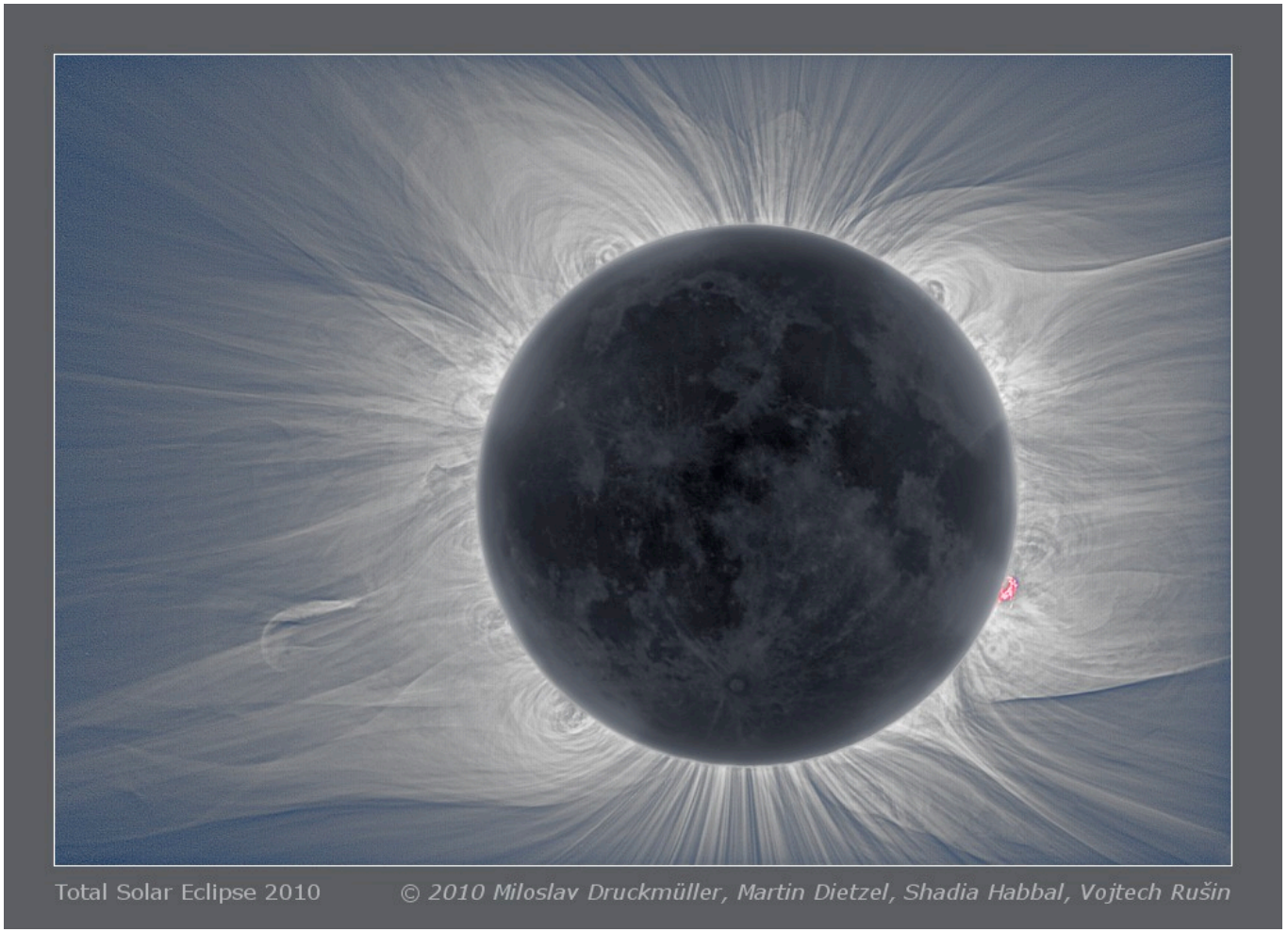
- Very little!
- I just wanted to show off our new and very precise oblateness data from RHESSI.
- With “global” measurements, such as the TSI and the solar shape, we are beginning to “see” inside the Sun.



Something slightly different

Total Eclipse of 2017

Total Eclipse of 2010

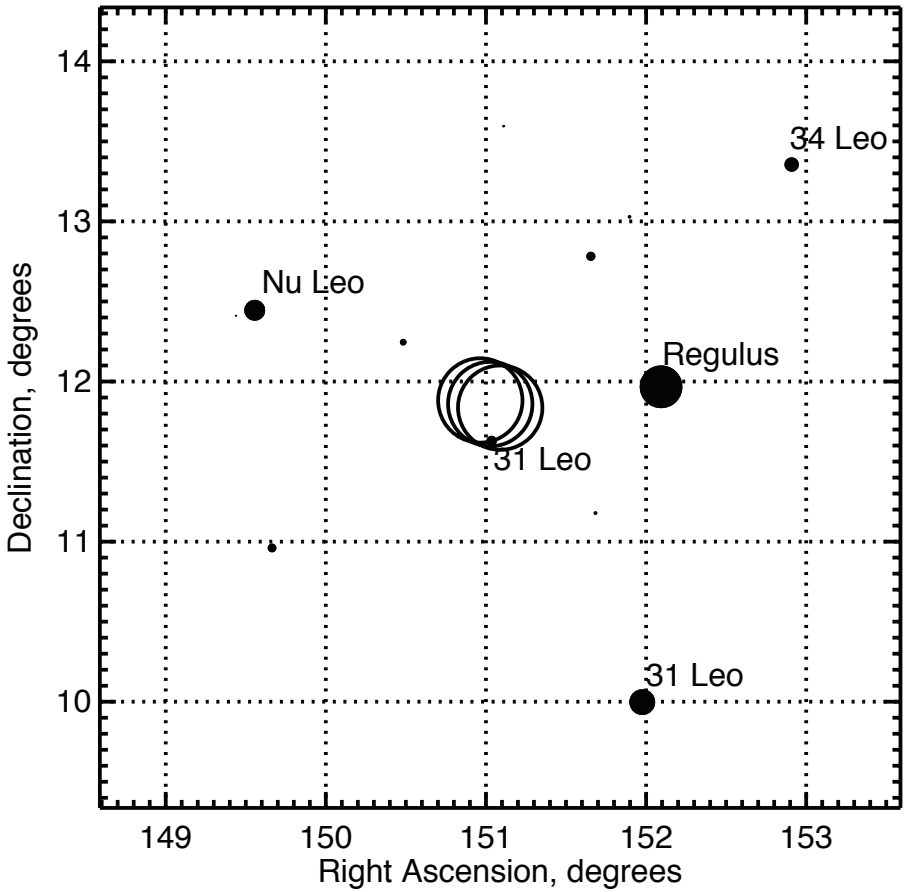


http://www.zam.fme.vutbr.cz/~druck/eclipse/Ecl2010t/0-info.htm

The Eclipse Megamovie idea

- The 2017 eclipse lasts for an hour and a half. Why not make a “megamovie” by stitching everybody’s images together?
- Such a move would be unprecedented scientifically,
- There are technical and logistical problems, but none that seem insurmountable. The US has good infrastructure for observers.

Eclipse 2017 and Einstein



Mills Observatory, 28 October 2011