NRLEUV2: A New Reference Spectrum for the EUV Irradiance of the Quiet Sun

Harry Warren and John Mariska

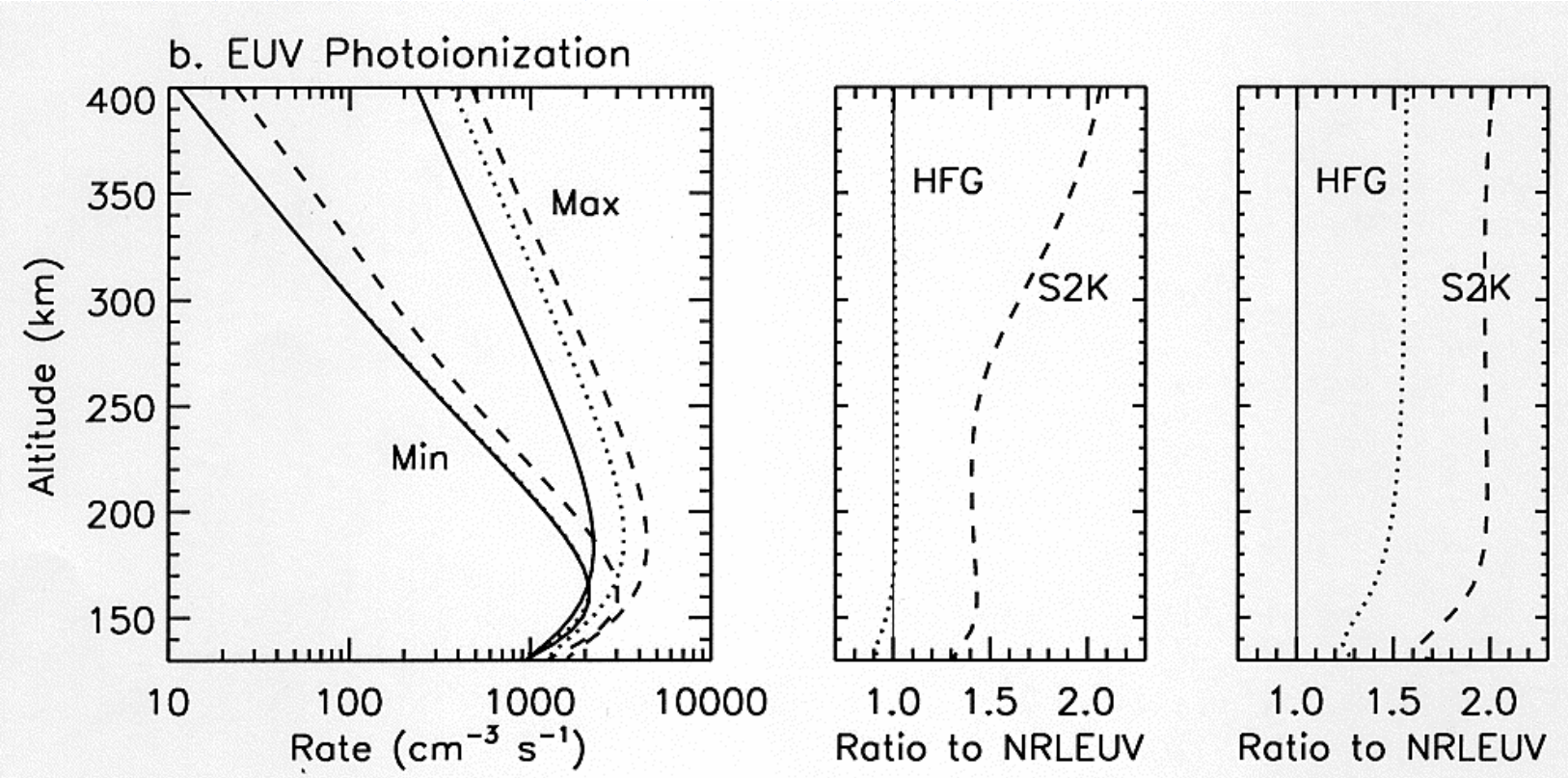
Naval Research Laboratory

Washington, DC 20375

The Sun-Earth Connection

- The Sun's extreme ultraviolet radiation (EUV, 50-1200 Å) strongly influences the Earth's thermosphere and ionosphere.
- Conditions in the Earth’s upper atmosphere play an important role in satellite operation and communication.
- The magnitude and variability of the solar irradiance at EUV wavelengths is not well understood.

Differences in Modeled Irradiances are Important to the Earth's Upper Atmosphere



AURIC photoionization calculation
Lean et al., JGR 2003

NRLEUV Model Overview

- We have developed a new approach to modeling EUV irradiance variability that complements observation and empirical modeling
- Elements of the model:
  - Intensities are computed from quiet Sun, coronal hole, and active region emission measures
  - Optically thick intensities are derived from observations
  - Limb-brightening curves relate disk-center to full-disk intensities
  - Areas of solar features are determined from full-disk solar images

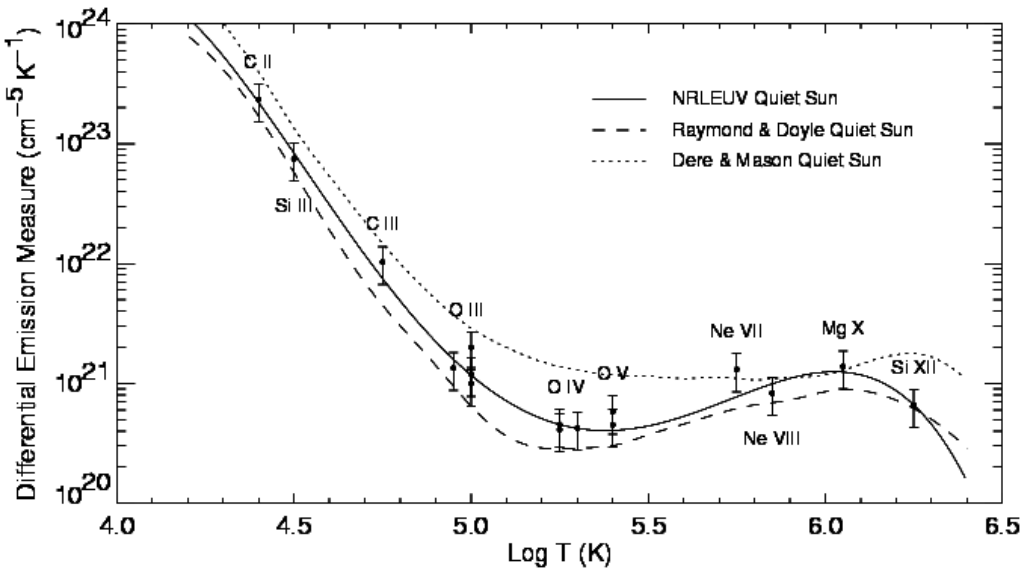
The Differential Emission Measure

$$I = \int \varepsilon(T_e) n_e^2 \frac{ds}{dT} dT = \int \varepsilon(T_e) \xi(T_e) dT$$

Differential Emission Measure

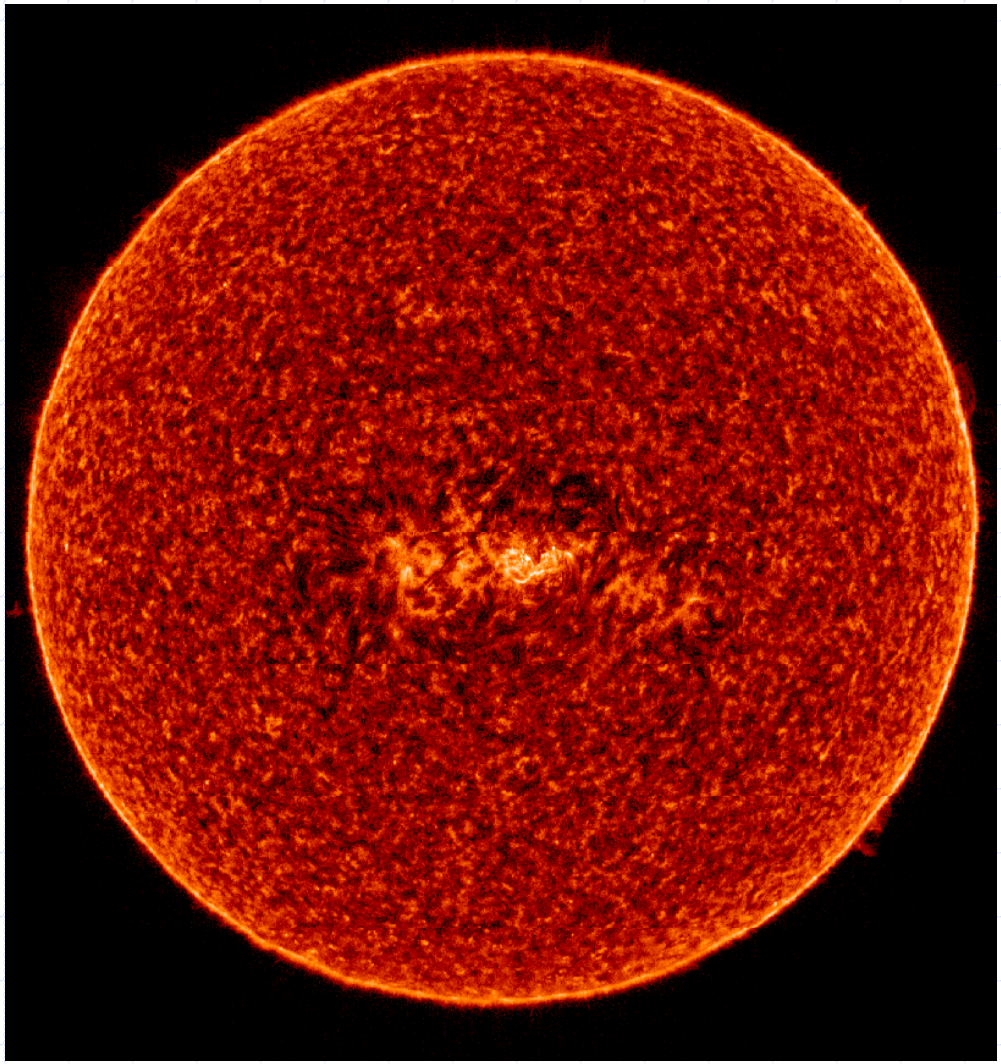
Emissivity

QS DEM from HCO Skylab data



Limb Brightening

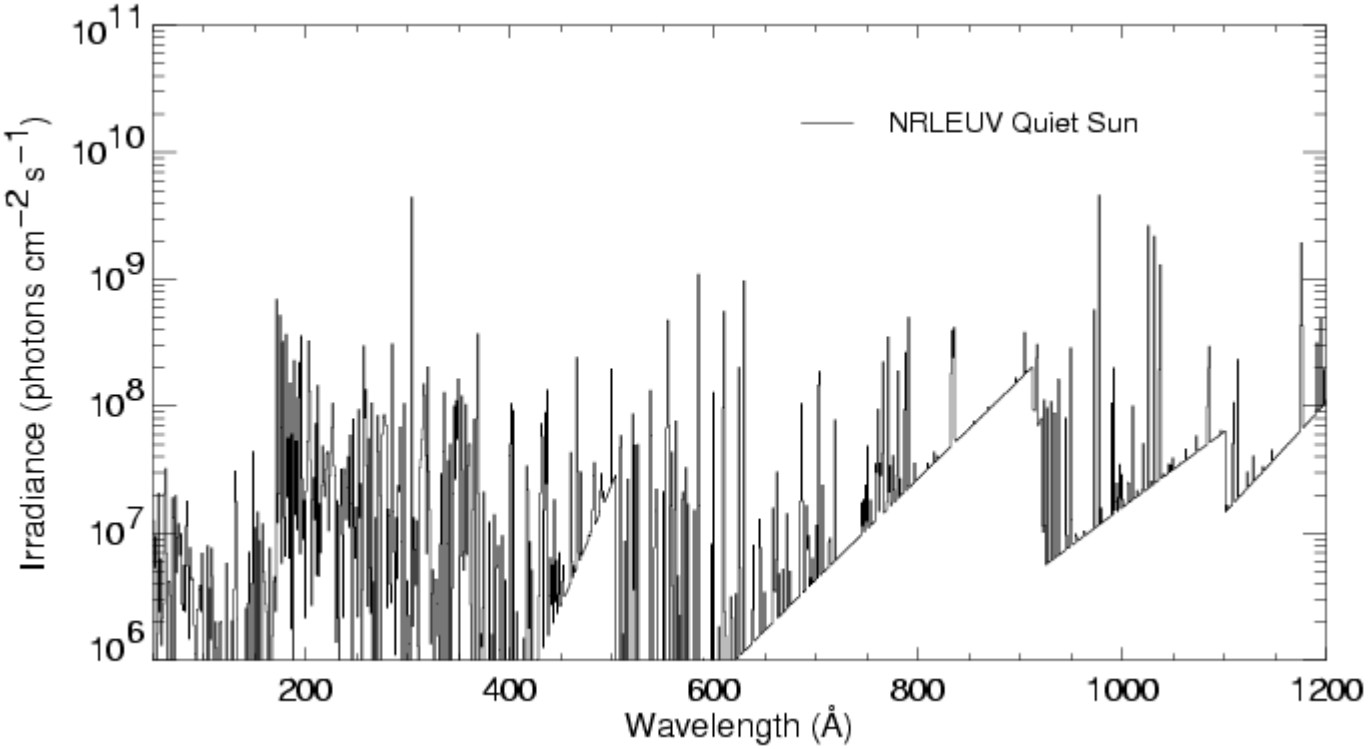
- Longer path length at the limb influences intensity
- Factor of ~2 for optically thin lines
- No limb brightening for optically thick lines



SUMER S VI 933 Å Spectroheliogram

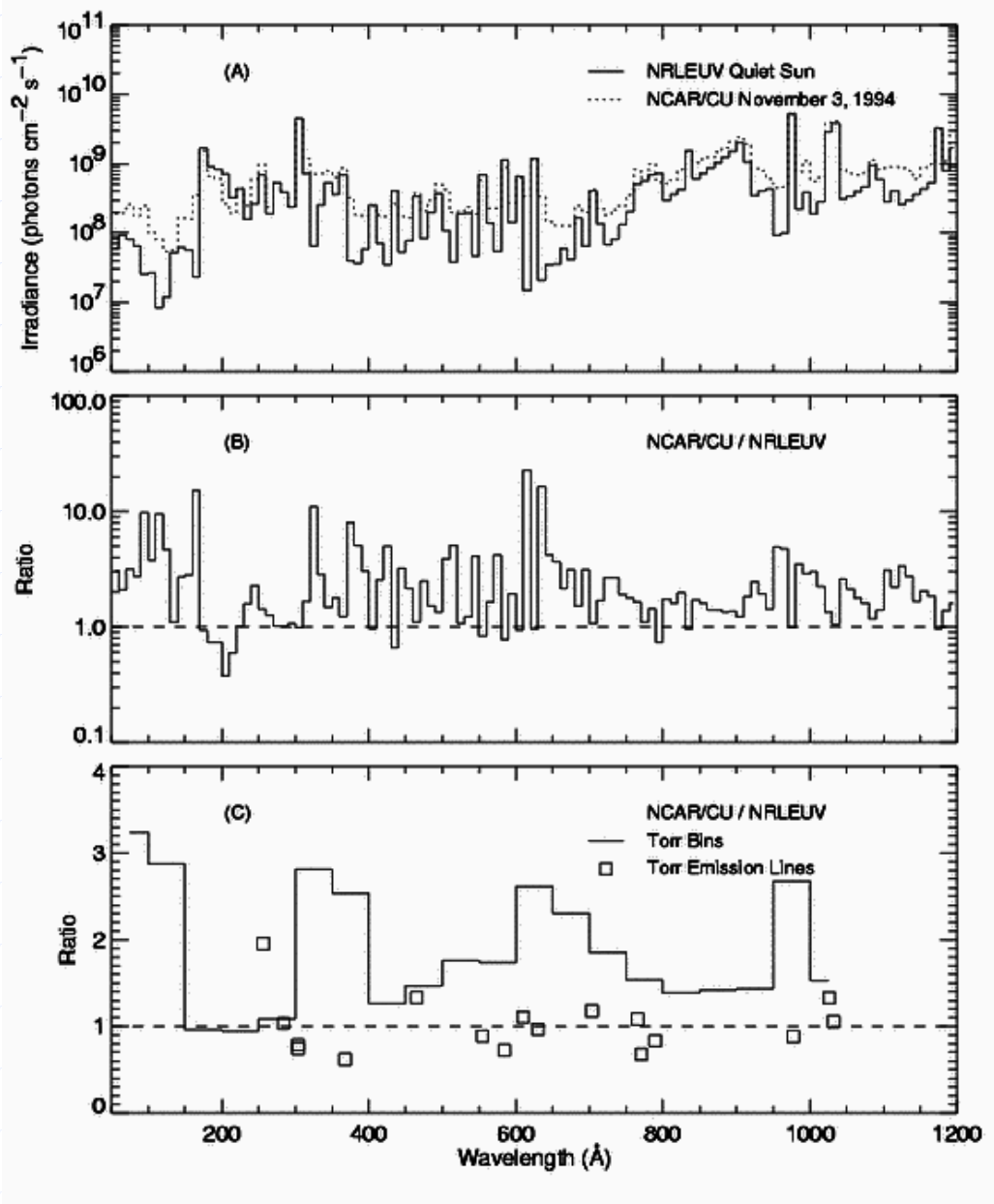
NRLEUV 1: Quiet Sun Irradiance Spectrum

$$F = \frac{\pi R_{sun}^2}{R^2} \langle I \rangle$$



Comparisons With Observation

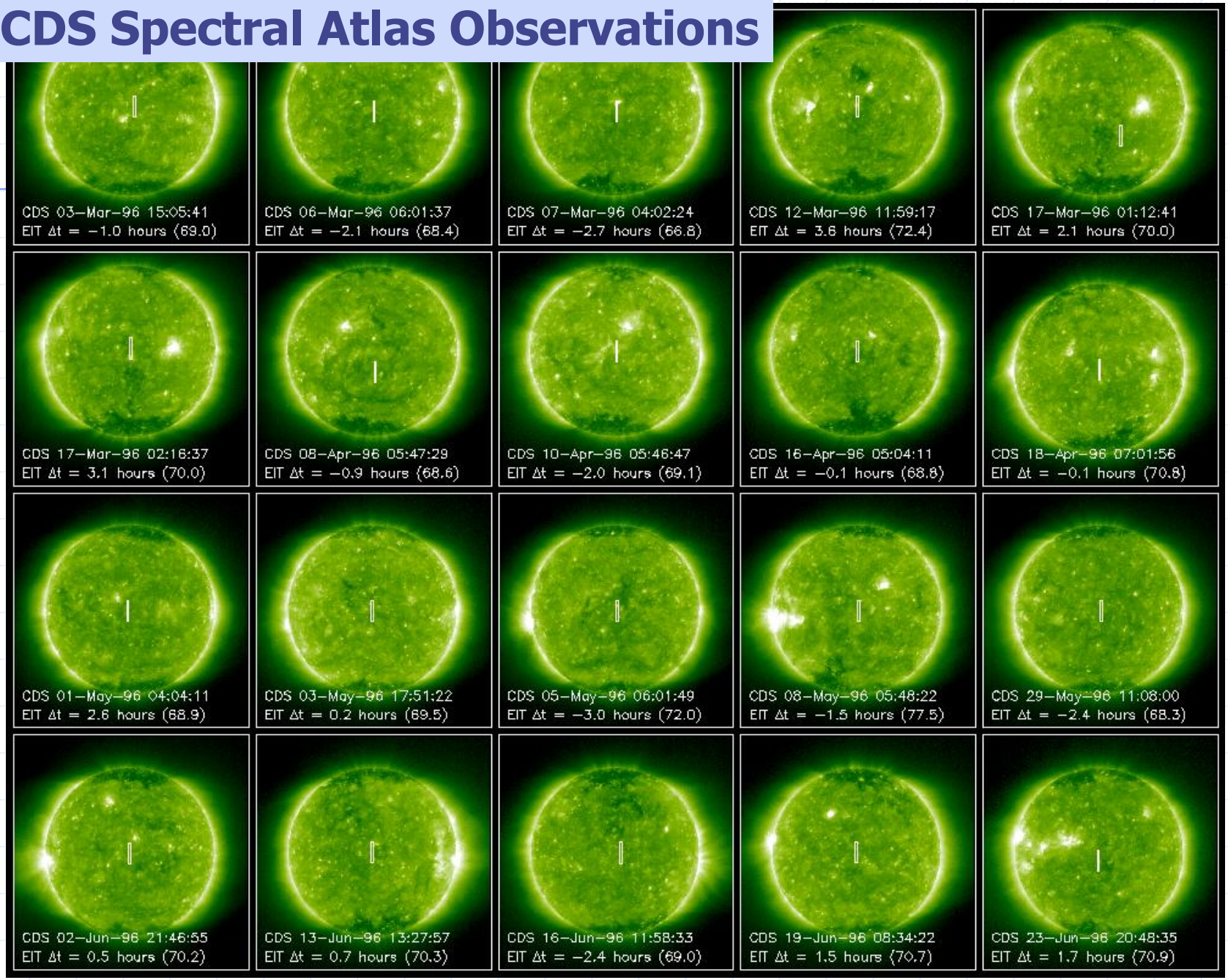
- 1994 NCAR/CU rocket flight
  - Good agreement for most lines
  - Differences when continuum intensity is low
  - Differences at very short wavelengths



NRLEUV 2: Update the Model Quiet Sun Irradiance Spectrum

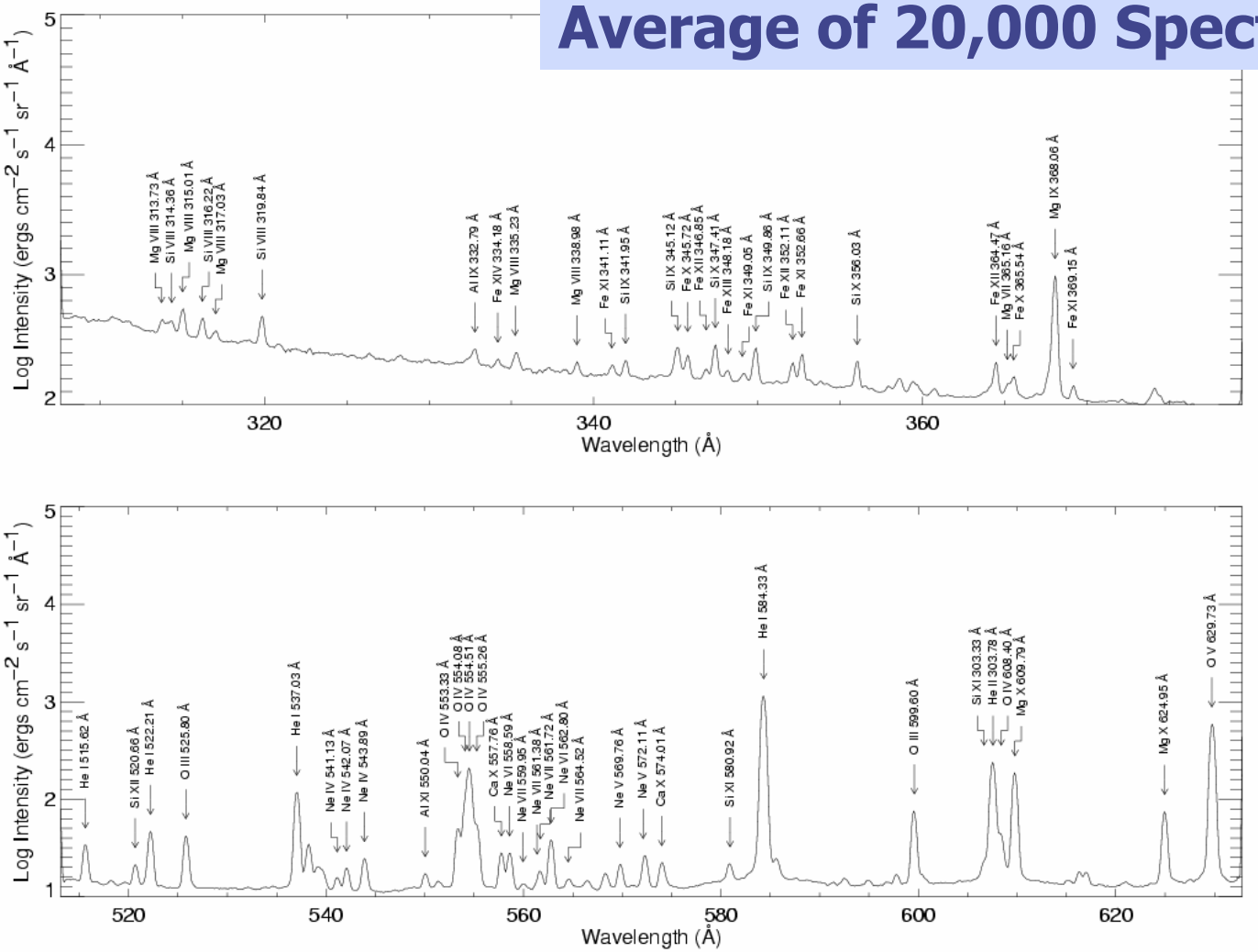
- SOHO spectrometers have many advantages over HCO Skylab instrument
  - Higher spectral resolution – more lines, fewer blends; but both CDS and SUMER must be used
  - More extensive observations – closer to true "quiet Sun"
  - Better calibration – more certainty in the intensities
- CHIANTI 4.0 has many more emission lines than earlier versions

20 CDS Spectral Atlas Observations



Average CDS Quiet Sun Spectrum – Intensities for 59 Emission Lines

Average of 20,000 Spectra

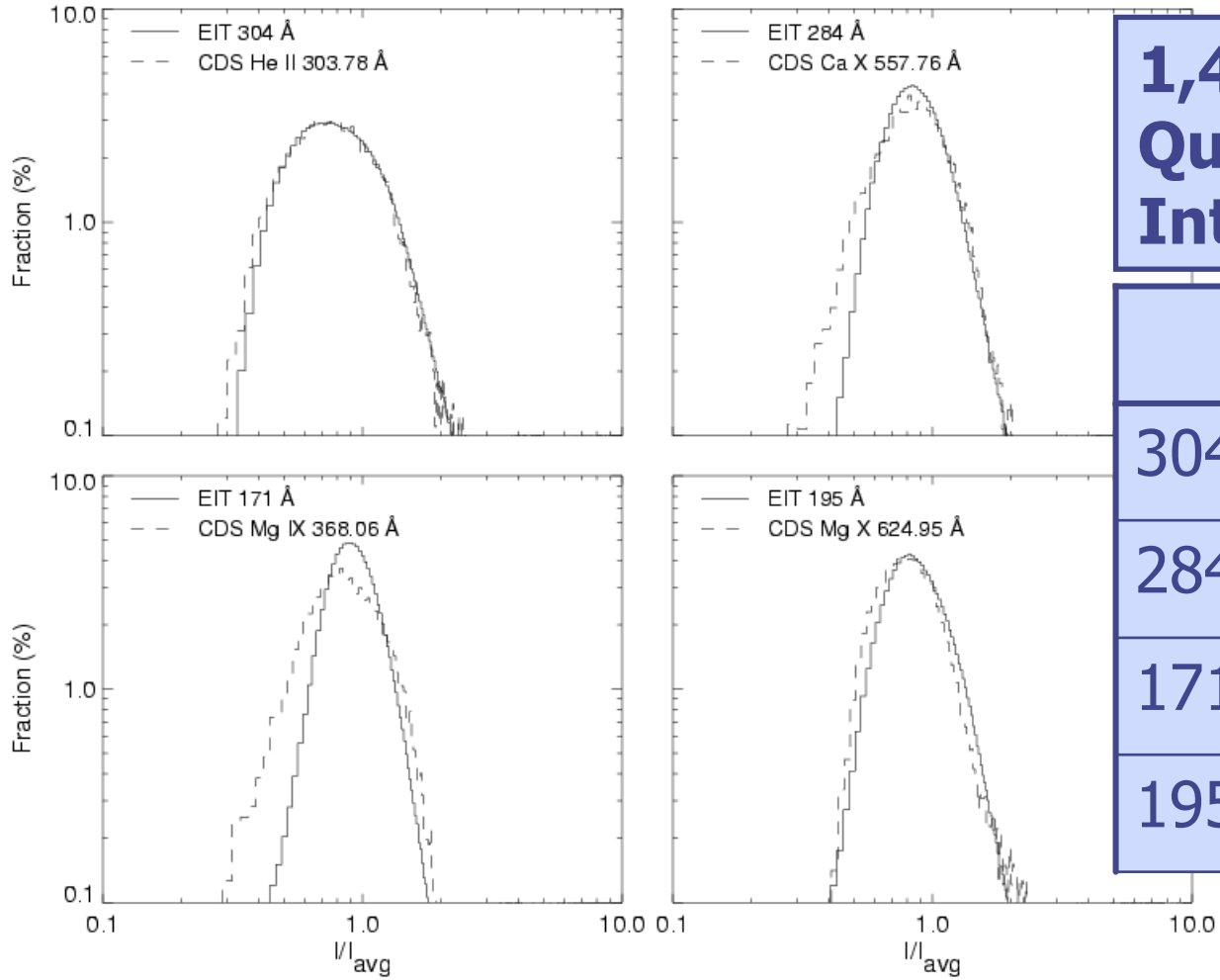


CDS and HCO Skylab Intensities

	CDS	Skylab
He I 584 Å	669.35	544.98
O III 599 Å	35.71	31.20
O V 629 Å	338.46	334.97
Mg X 625 Å	36.91	51.43
Si XII 521 Å	4.98	25.44

- Generally agree to within ± 25%
- Si XII 521 Å different by 5x!
- But have we measured the quiet Sun?

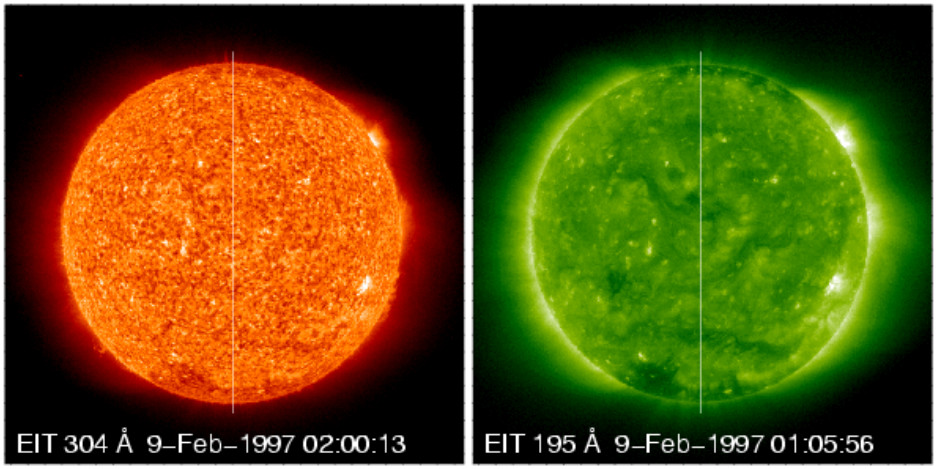
CDS and EIT Histograms

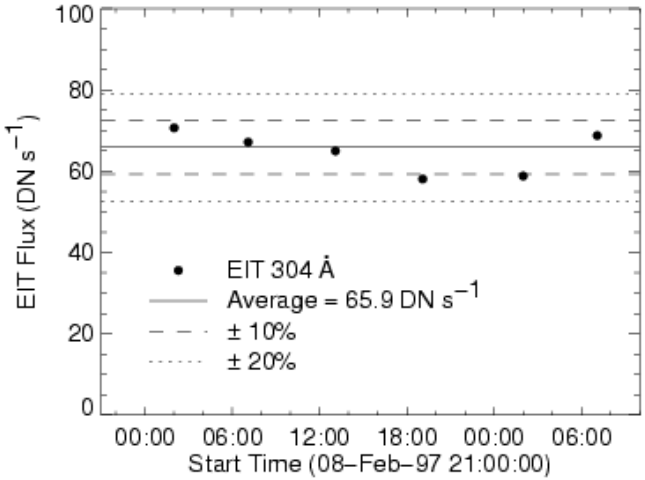


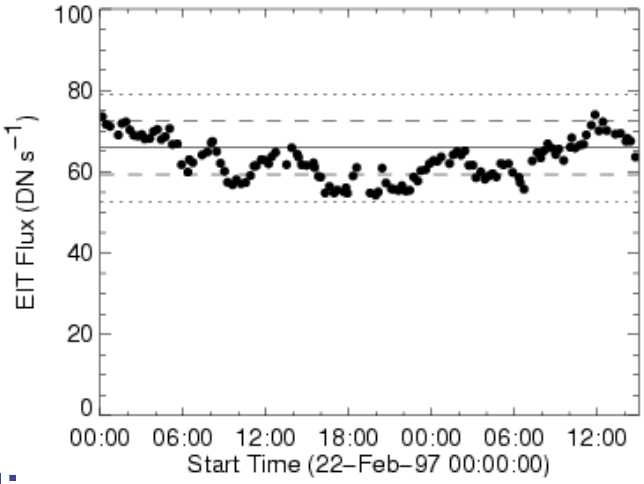
1,460,000 EIT Quiet Sun Intensities

λ	DN/s
304 Å	65.9
284 Å	2.2
171 Å	128.4
195 Å	63.2

SUMER Meridional Scan Data: Disk-Center Intensities for 114 Emission Lines

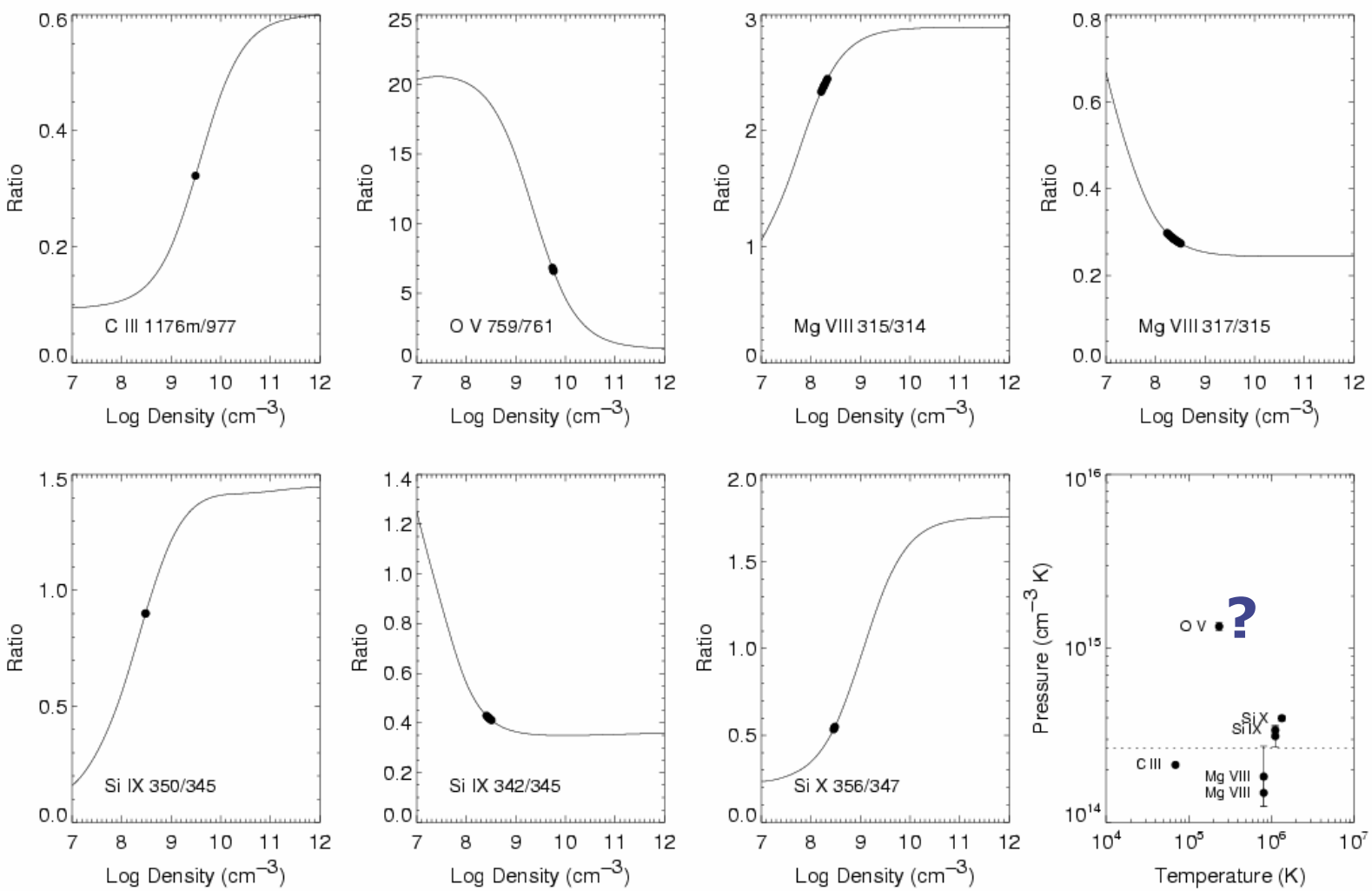




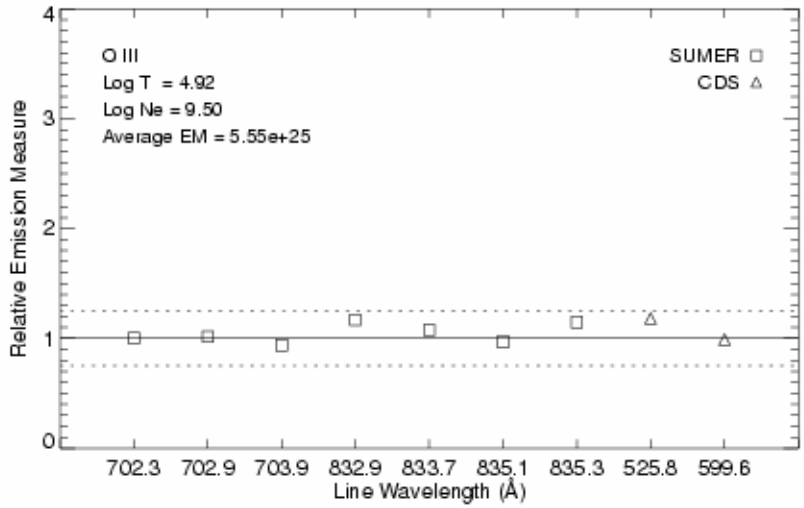


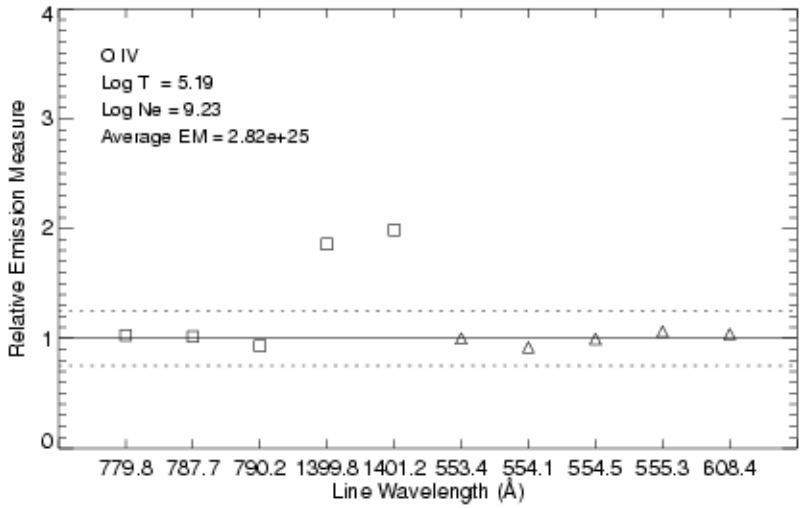
- ~ 7000 spectra for each emission line

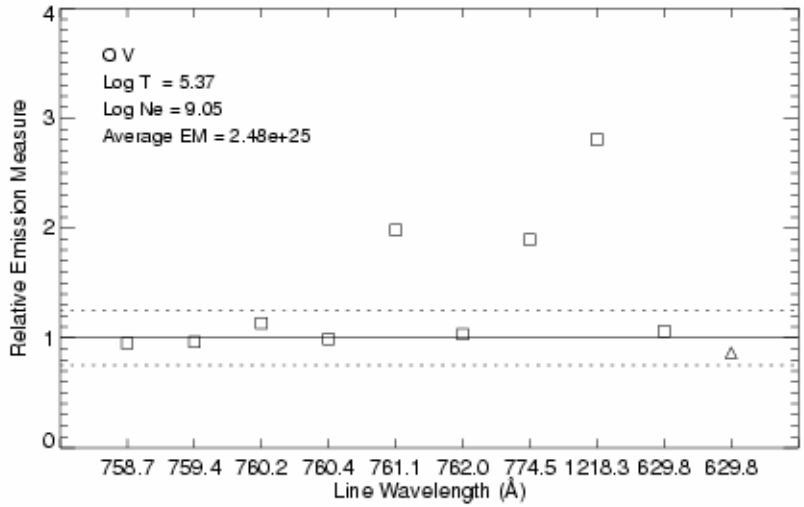
CDS and SUMER Density Sensitive Line Ratios Indicate a Pressure of ~ 3×10^{14}

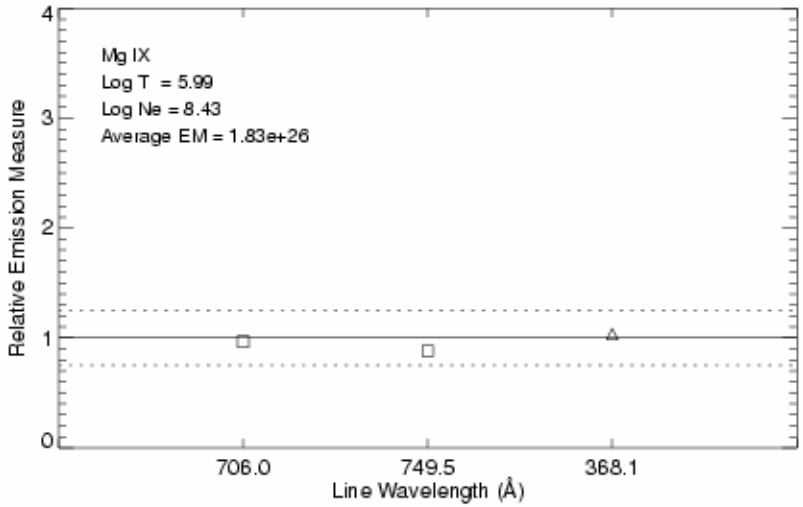


CDS and SUMER Intensities are Generally Consistent: Examples

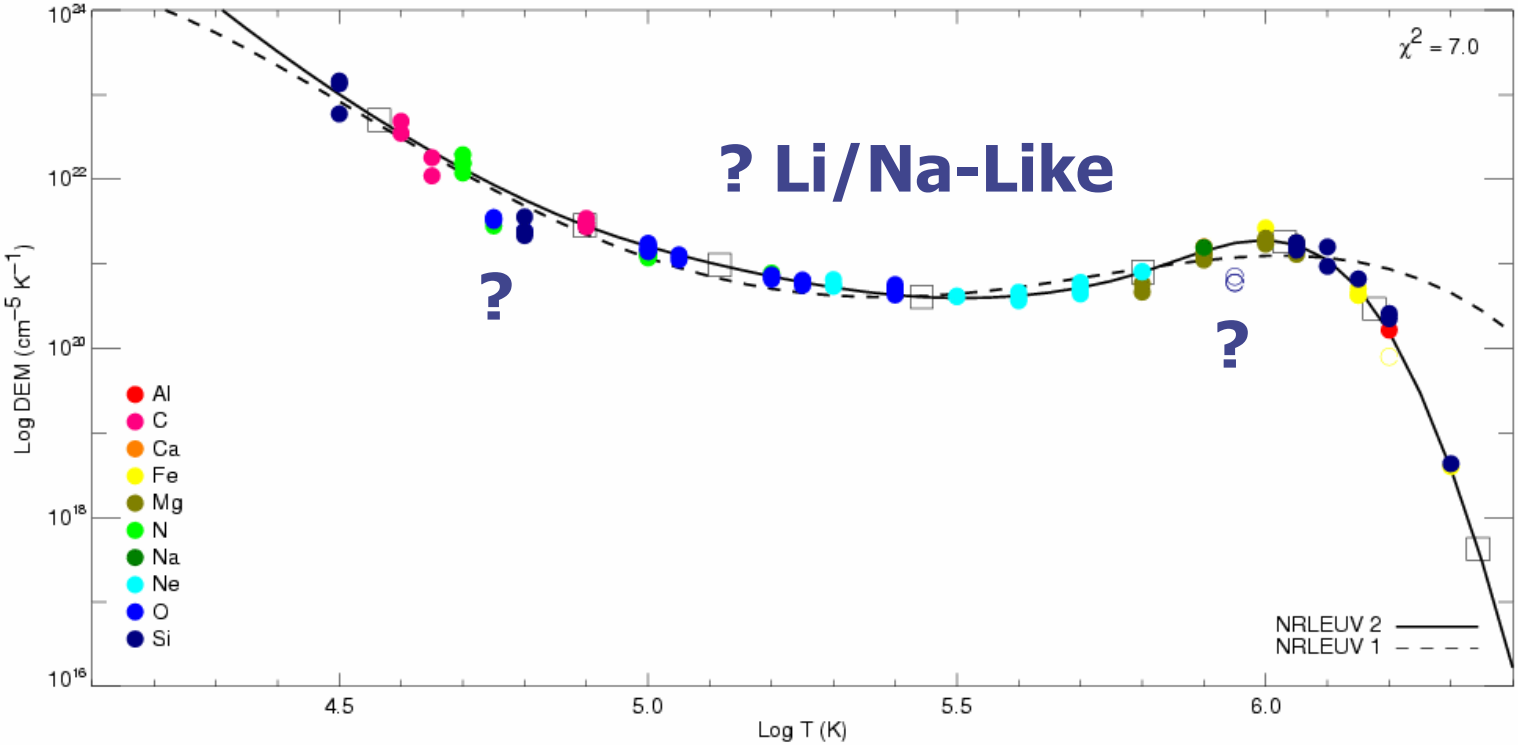






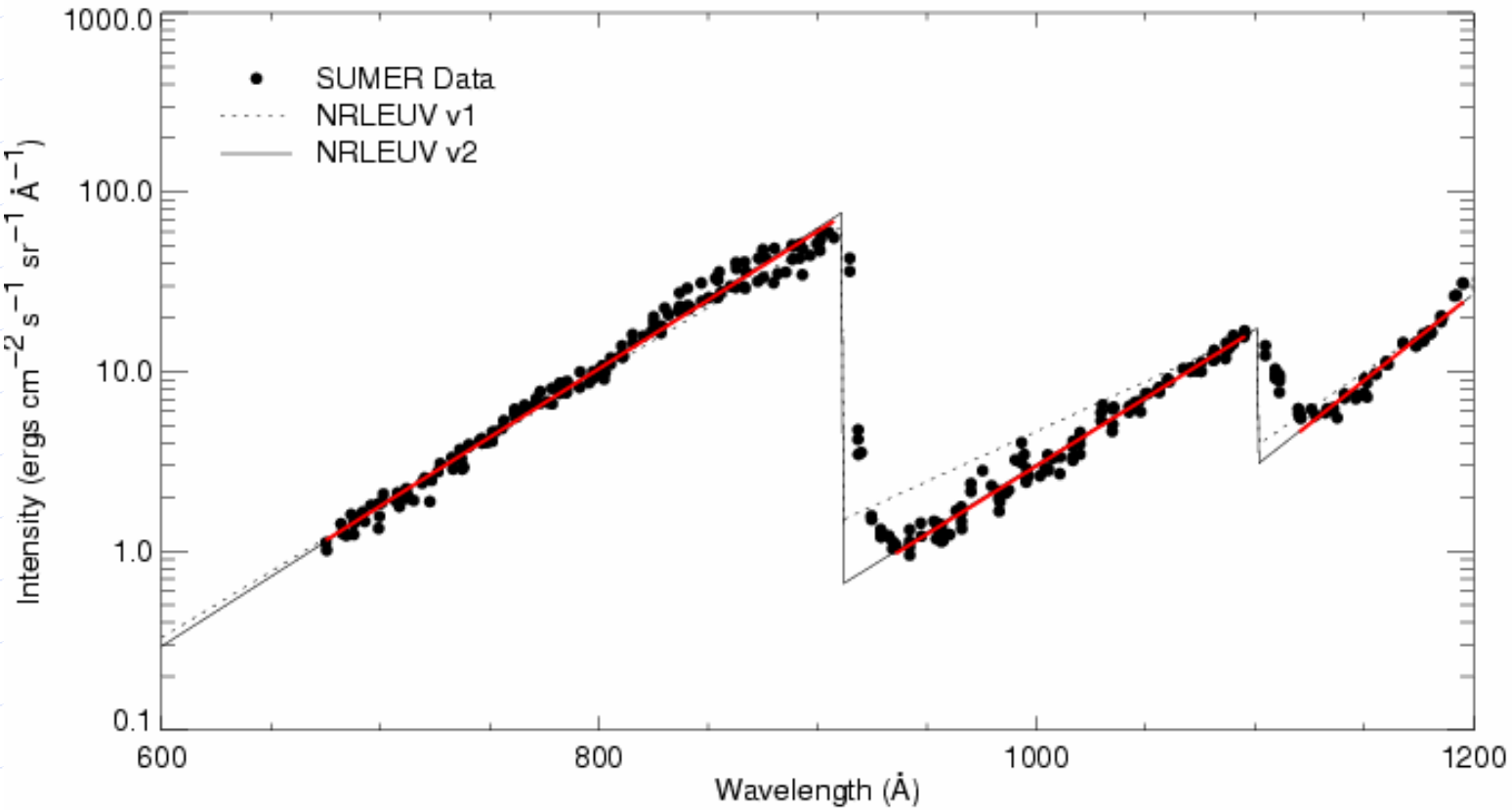


Quiet Sun DEM Derived From CDS and SUMER Data



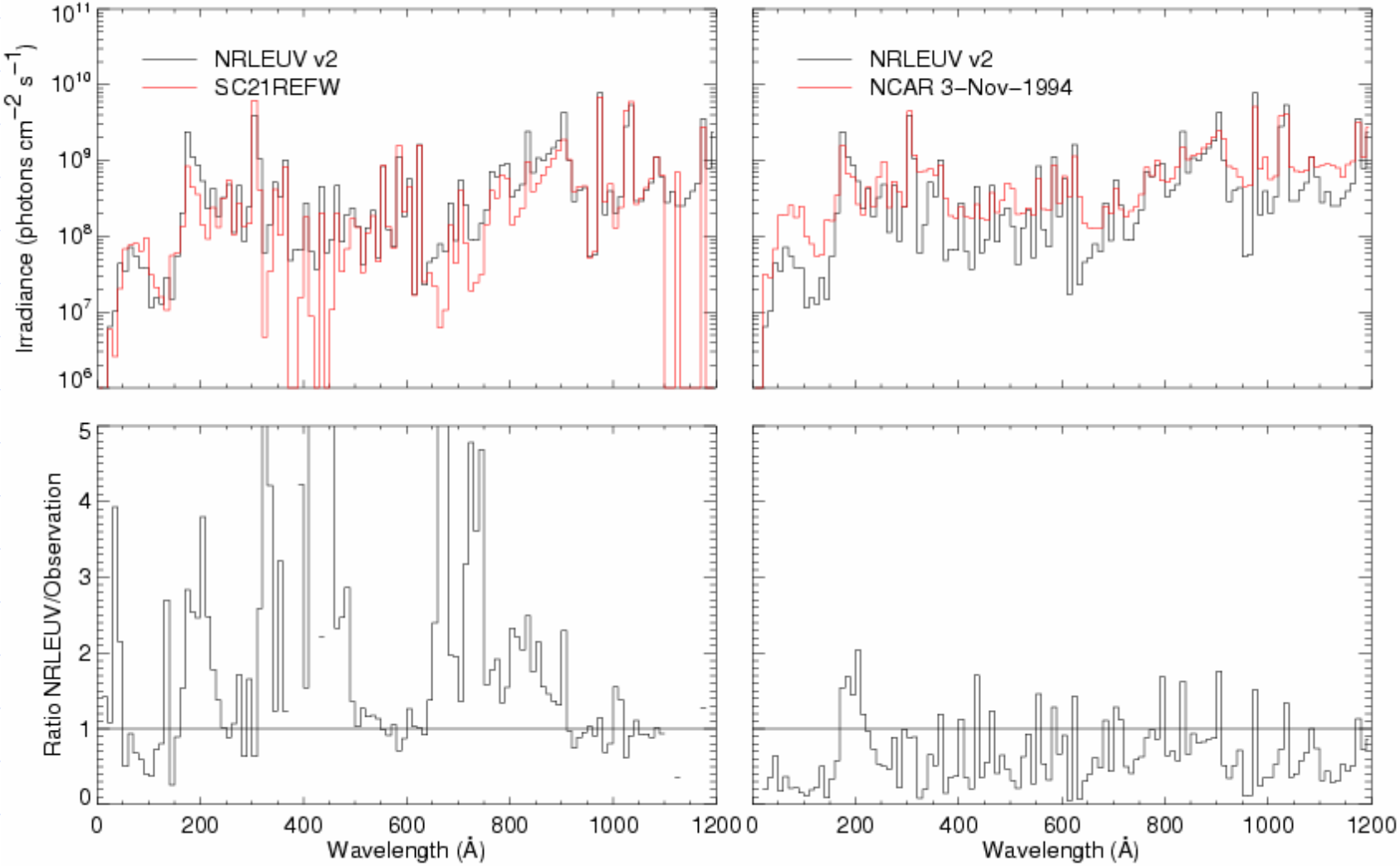
- Generally good agreement between SOHO and Skylab DEMs
- Big differences at high temperatures

SUMER Observations of the EUV Continua



- Generally very good agreement between SUMER and Skylab observations

Comparisons of NRLEUV Quiet Sun Irradiance Spectrum With Observations



Many Differences Between Model and Observation Persist!

- Differences when continuum intensity is low
  - NRLEUV is higher than SC21REFW, lower than the 1994 NCAR/CU rocket measurement
  - How to resolve?
- Differences at very short wavelengths
  - NRLEUV and SC21REFW agree at short wavelengths (<150 Å), but are both lower than the rocket measurement.
  - Resolve with stellar data?

Summary

- We have performed an extensive analysis of CDS and SUMER quiet Sun observations. We find
  - CDS, SUMER, and HCO Skylab calibrations are generally consistent to about ± 25%
  - Current atomic data is consistent with majority of observations, but many unresolved issues persist.
  - Emission measure at high temperatures is much lower than before
- The new version of the NRLEUV quiet Sun irradiance spectrum is similar to the old one.