# Interpreting the IR/WL/UV/EUV energy distribution in the impulsive phase of a solar flare

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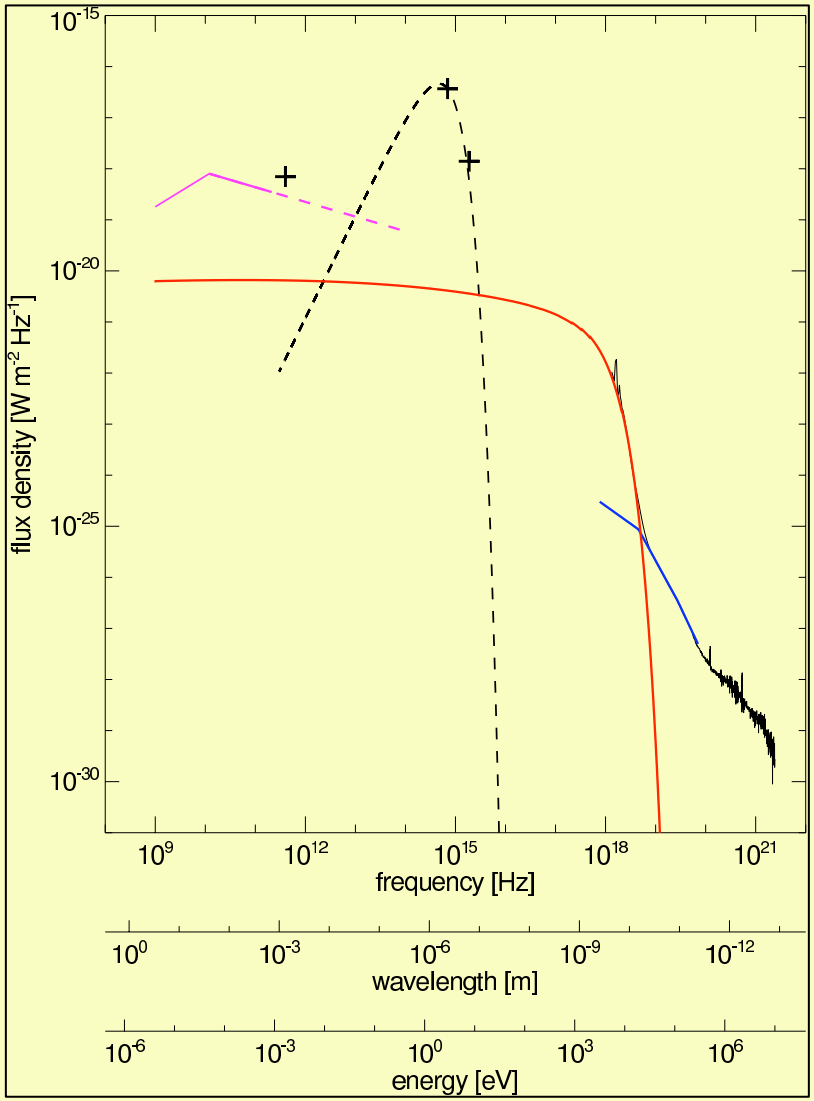
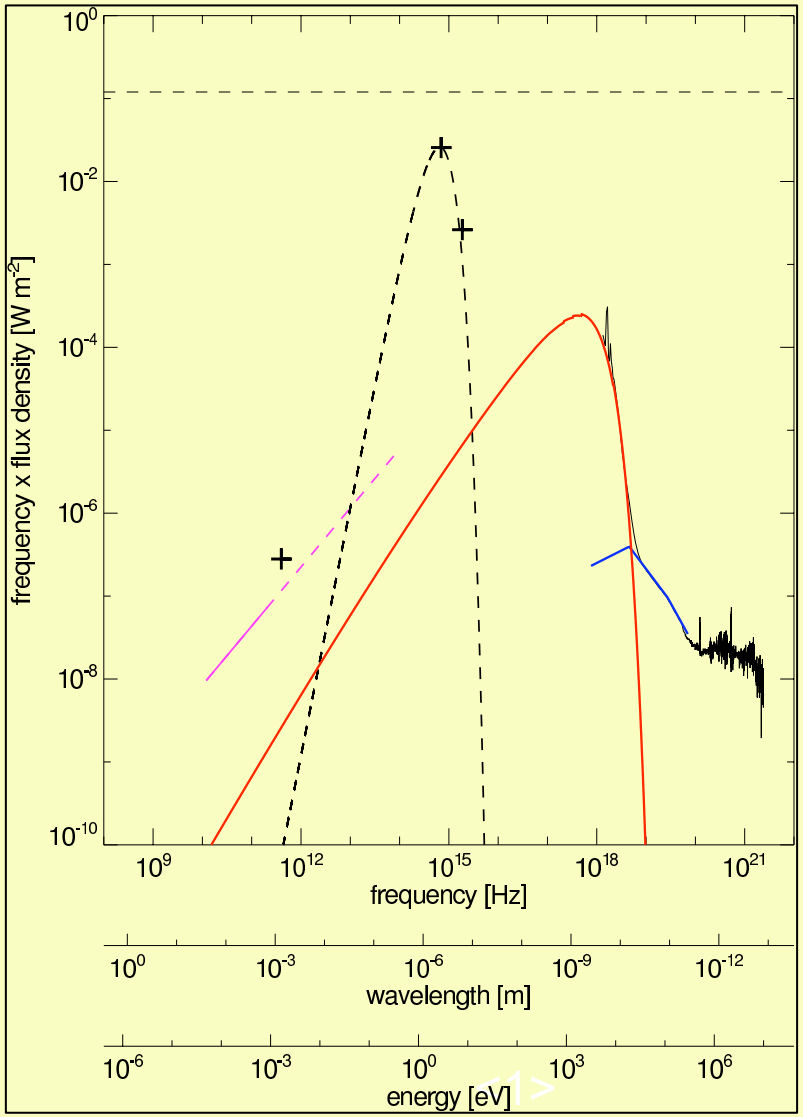
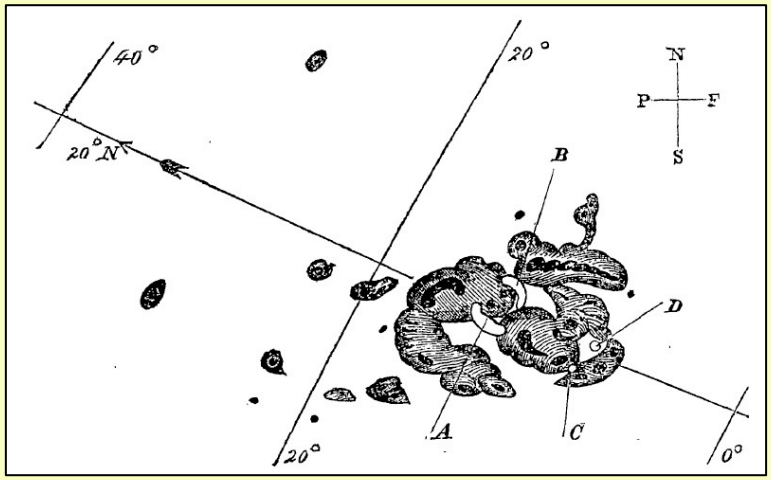
# Flare Spectral Energy Distribution



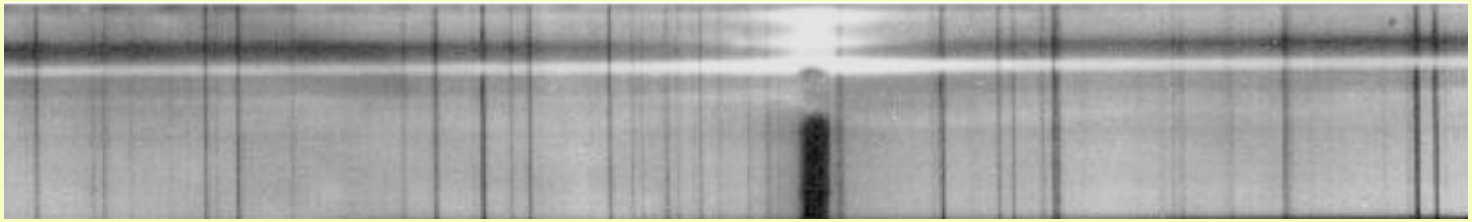



# Optical imaging and spectroscopy




Carrington 1859 original flare

- Flare emission is intermittent
- Flare emission is energetic

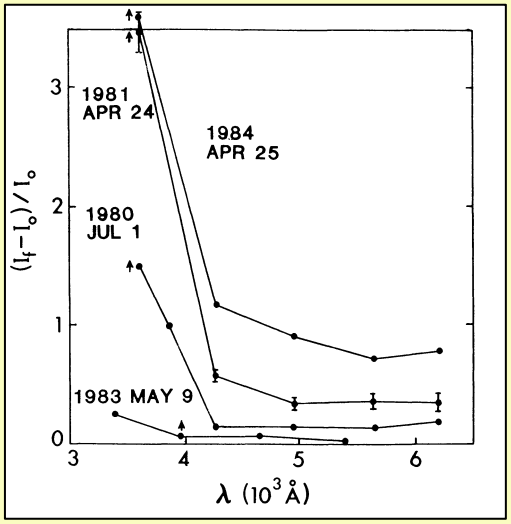


Babin & Koval 2007

- It has been difficult to put the slit on the flare at the right time and place
- Much early observational work was on film
- There is little modern CCD-based flare imaging spectroscopy

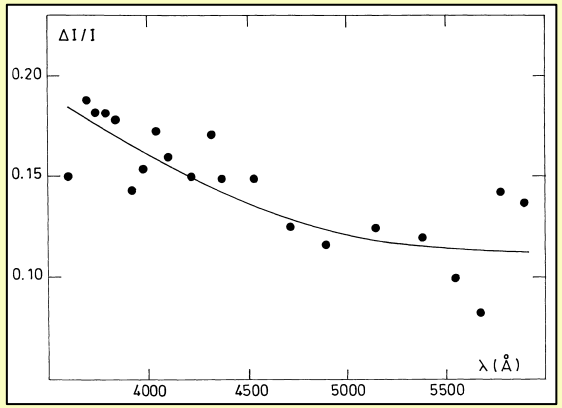
# Spectral energy distributions

Neidig, 1989: Balmer jump



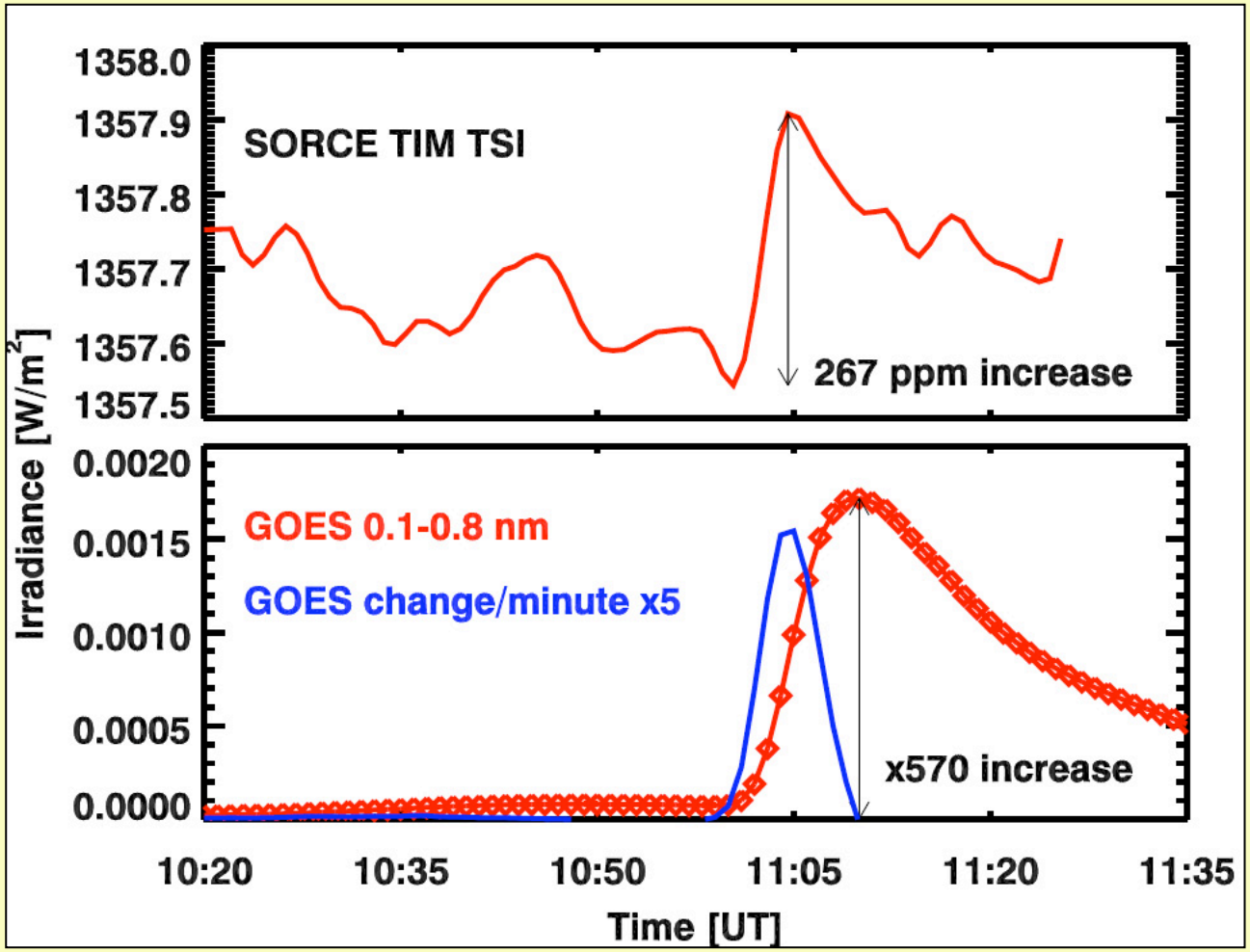

The impulsive-phase spectra exhibit a Balmer jump: a hot optically-thin layer has formed

The gradual-phase spectra tend to be continuous, implicating optically-thick $H^-$ opacity



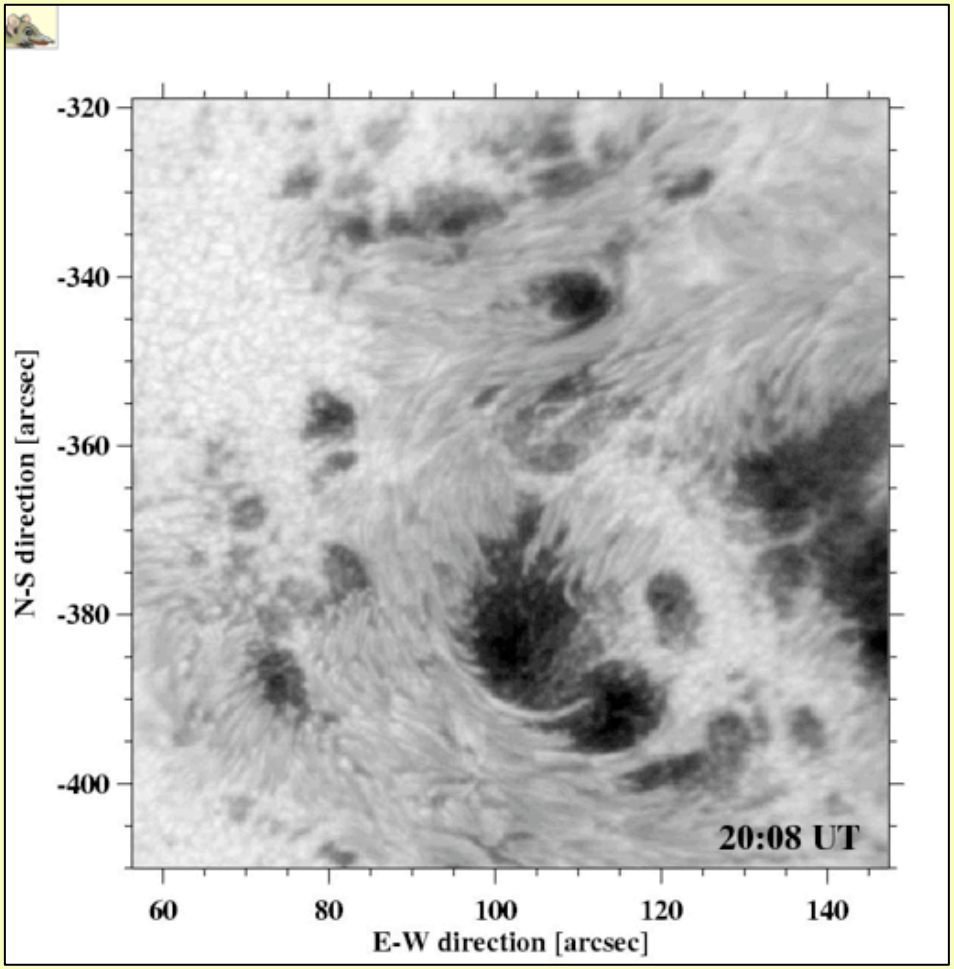

Boyer et al. 1985

# First bolometric observation of a solar flare




Woods et al. 2004

# Flare observation at 1.56μ
# "opacity minimum region"

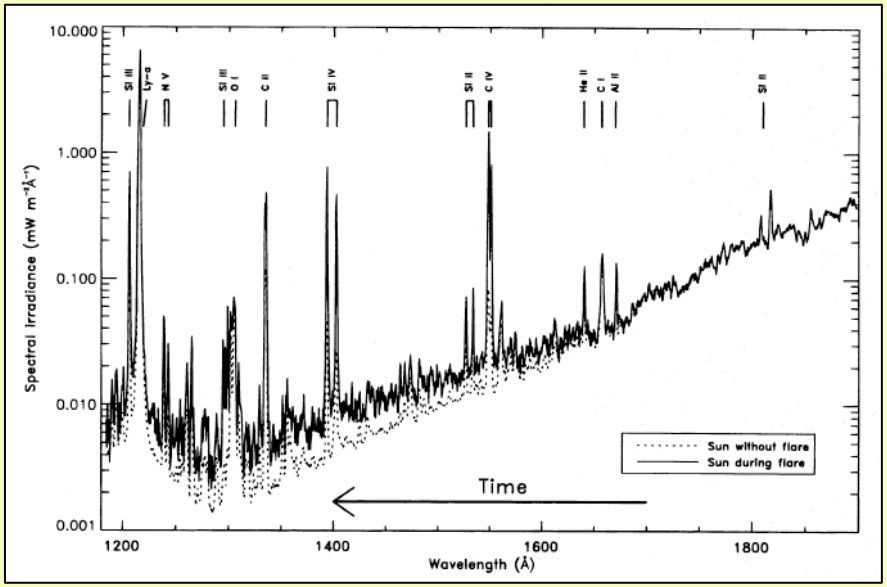


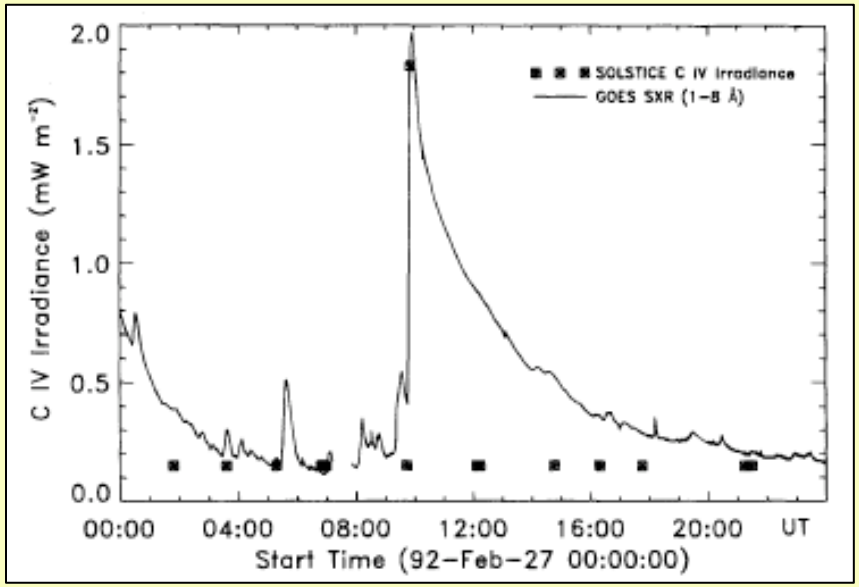

Xu et al. 2004

# Basic constraints on impulsive-phase energetics

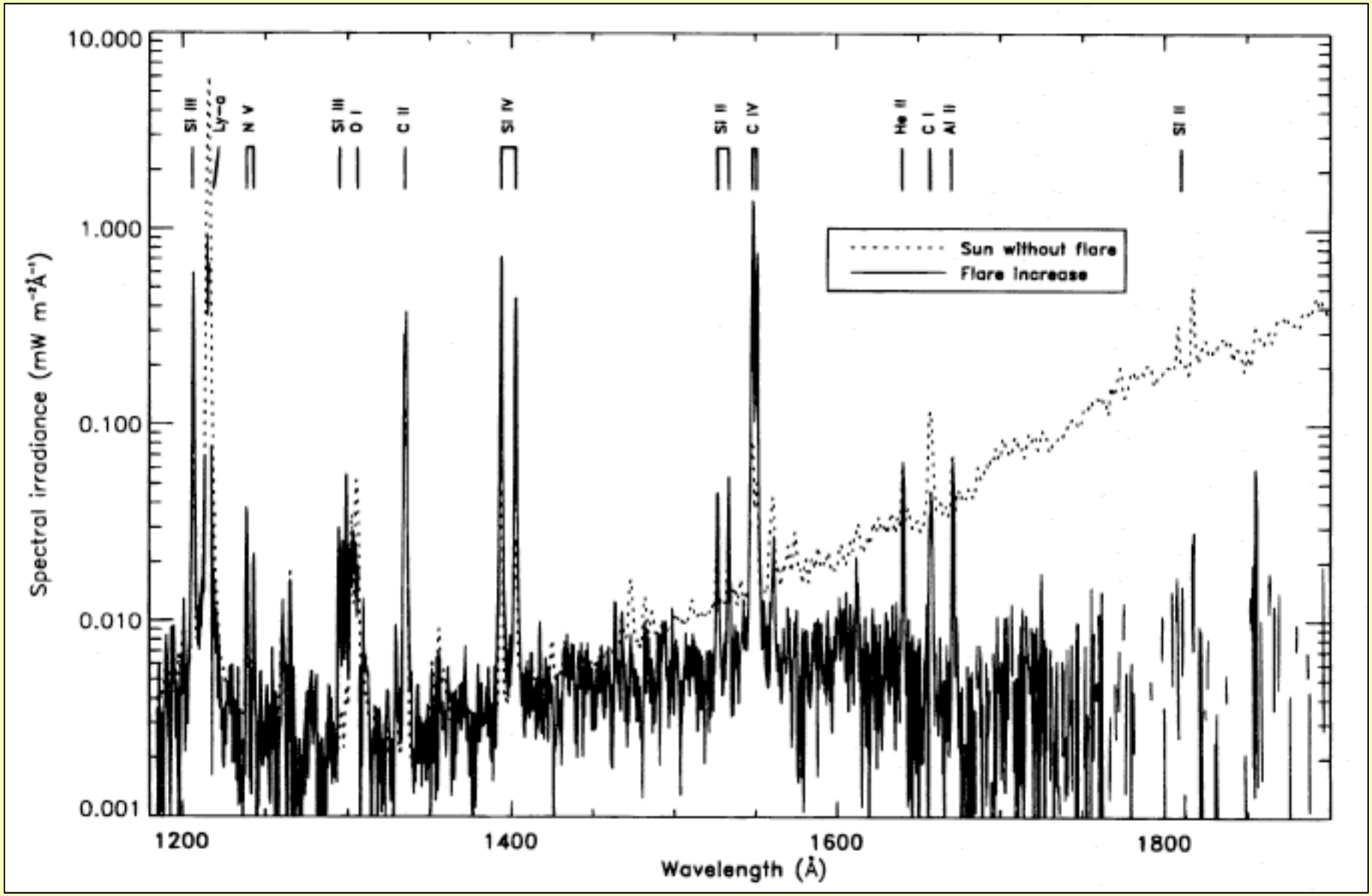
- Fast electrons need to be energized
- The UV/VUV continuum probably contains the bulk of the flare luminosity
- The luminosity is highly localized in space and time

# Brekke et al. 1995: a unique VUV spectrum from UARS




- *We expect soon to be able to see many more detailed spectra from SDO/AIA, at 10 s time resolution*


10.000
1.000
0.100
0.010
0.001
Spectral irradiance (mW m⁻²Å⁻¹)
1200
1400
1600
1800
Wavelength (Å)
Si III
Ly-α
N V
Si III
O I
C II
Si IV
Si II
C IV
He II
C I
Al II
Si III
Sun without flare
Flare increase

time

# Absence of UV spectrophotometric information in the impulsive phase

- We know there is Balmer continuum from Neidig's broad-band observations
- There is almost no useful UV/VUV spectroscopy of solar flares, and even less Ly-$\alpha$
- Stellar spectrophotometry is also weak, and may not be easily applicable

# Other guides to the physics of the UV/VUV continuum

- Hard X-ray and $\gamma$-ray emission
- Wave formation
- Radiation hydrodynamics modeling

# Parting quotations

"Follow the **money**" (= "Follow the energy"?)

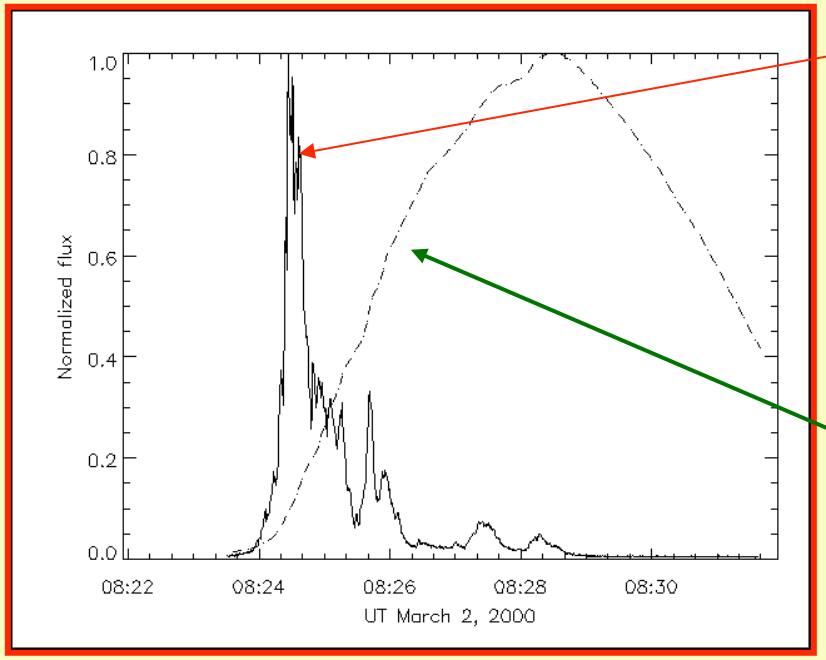
Deep Throat, 1976

"I would like to emphasize that the 'old fashioned' H$\alpha$ observations of flares **should** not be underestimated by space scientists, as is often the case."

Z. Svestka, 1976

OTHER SLIDES

# Impulsive phase and gradual phase: The Neupert effect




*Impulsive phase* – primary energy release
- hard X-rays (10s of keV)
- white light, UV, μwaves - broad spectrum
- duration < few minutes
- intermittent and bursty time profile, 100 ms
- energy injection
- soft-hard-soft spectral evolution

*Gradual phase* - response to input
- thermal emission (kT ~0.1-1 keV)
- rise time ~ minutes
- coronal reservoir

Impulsive phase:
- > few tenths of the total flare energy released (up to $10^{32}$ ergs)
- Significant role for non-thermal electrons
- CME acceleration