

The Mees CCD Imaging Spectroscopy Synoptic H α “Flare-mode” Database

KD Leka

NorthWest Research Associates

Highlights:

- High-cadence AR-targeted imaging spectroscopy scans with broad spectral coverage, fair spatial resolution, full AR spatial coverage.
- MCCD ran 1989—2005, almost daily when Mees Solar Observatory was open.
- Data written directly to Exabyte tape, stored. NWRA secured new NASA money to enable its rescue.

Optical Path Highlights:

- 25cm spar-mounted coronagraph-quality light feed, with image rotator.
- 3m Coudé Spectrograph feeding normal-incidence or Eschelle gratings.
- Quad-cell image-stabilizer, drift monitor/tracker.
- solar image moved across slit with scanning mirror; slit-jaw camera provides video-rate context images.

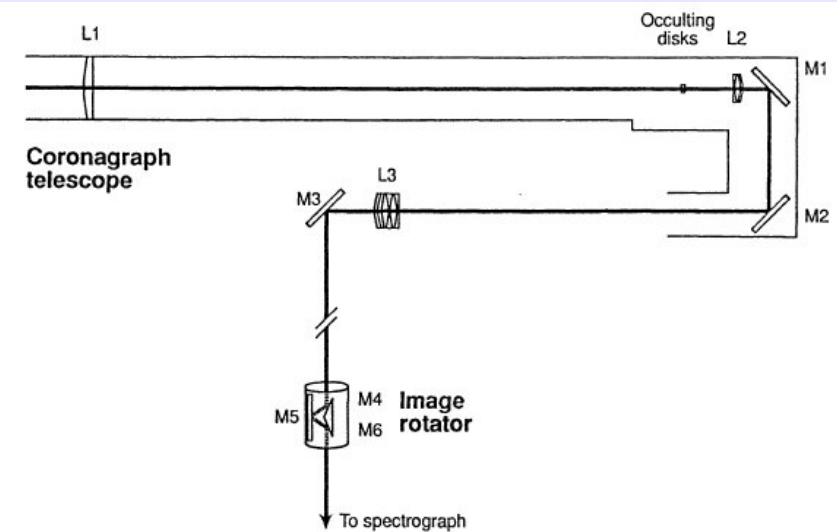


Fig. 1. Optical diagram of the 25 cm coronagraph telescope. At the focus of the objective ($L1$) is a selection of occulting disks which allow the corona to be observed. The second objective ($L3$) corrects for the chromatic aberration of the telescope. The Coudé mirror ($M3$) directs the sunlight into the image rotator, which removes rotation from the image plane. In the current setup, the MCCD optical bench immediately follows the image rotator (see Figure 4).

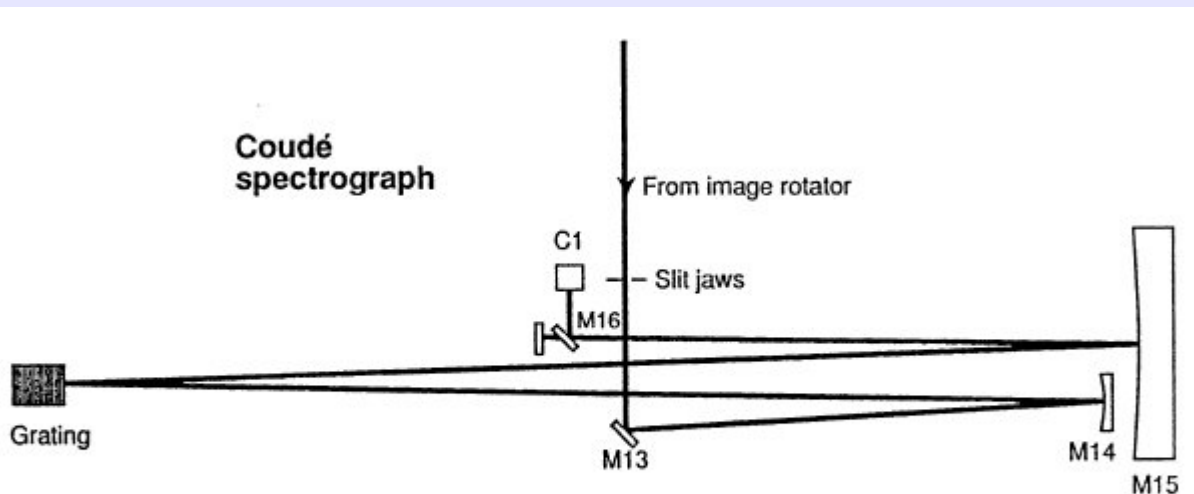


Fig. 2. Optical diagram of the 3.0 m Coudé spectrograph. The slit jaws allow sunlight to enter the spectrograph, which is collimated by $M14$, dispersed by the diffraction grating, and focused by the camera mirror, $M15$. A small flat mirror ($M16$) feeds part of the spectrum to the Photometrics CCD camera, $C1$.

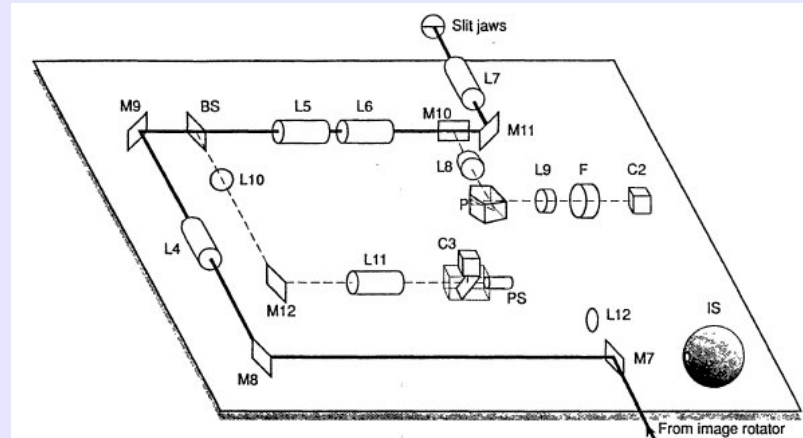


Fig. 4. The MCCD optical bench. The image rotator directs light onto the bench at $M7$. The main optical beam directs light via $M8$, through $L4$ to $M9$, through $L5$ and $L6$ to $M11$, then through $L7$ onto the spectrograph slit. The image monitor beam takes light from the closed shutter mirror $M10$, through $L8$, the pentaprism P , $L9$, and a narrow-band filter F to the camera $C2$. The fast guider beam directs some light via the beam splitter (BS) through $L10$, off $M12$, and through $L11$ to the detector package consisting of $C3$ and the position sensor (PS). Finally, the integrating sphere (IS) and a field lens $L12$ produce a calibration image for flat fielding purposes.

Optical Performance Highlights:

- Broad spectral range (far blue into near IR)
- High resolving power
- Coronal-quality site and optics*

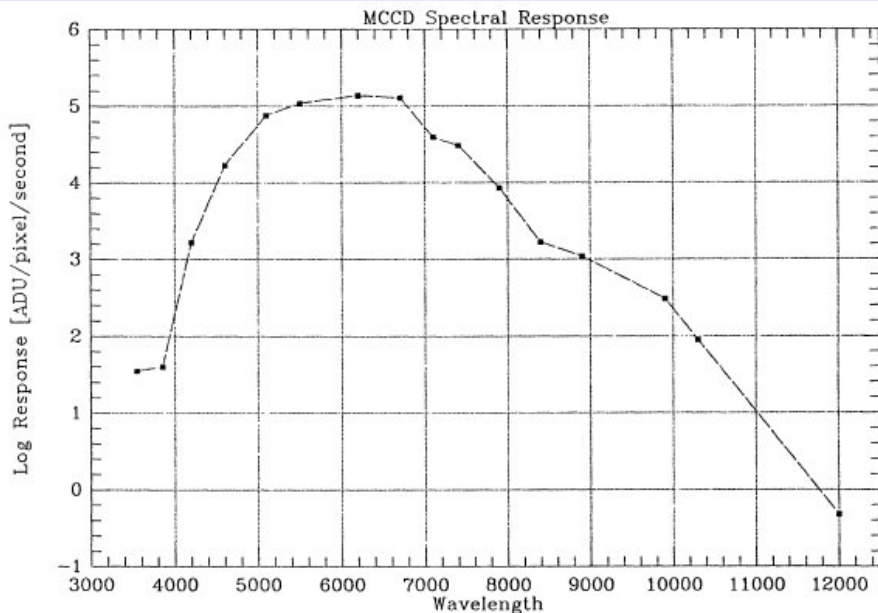


Fig. 3b. The spectral response of the MCCD from $\lambda 3550 \text{ \AA}$ to $\lambda 12000 \text{ \AA}$. This graph shows the solar flux, in ADU (analog-digital units) per second per pixel, detected by the Photometrics CCD camera at the spectrograph focus. We observed several solar continuum regions at the center of the solar disk at local noon, with the normal incidence grating (No. 1) (with a dispersion of $8 \text{ pixels \AA}^{-1}$) no pre-filters, and a 60 \mu m wide slit. From this graph we can calculate the exposure time needed for any observation, using simple linear extrapolations to the particular observational parameters. Note that the Photometrics camera saturates all 12 bits at a value of $\log_{10}(4095) \approx 3.6$.

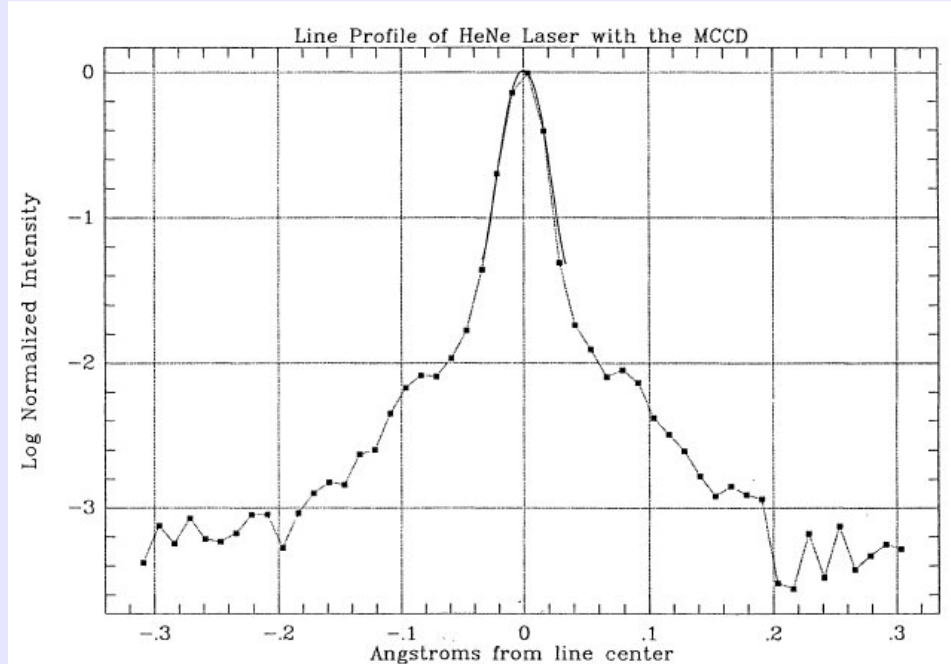
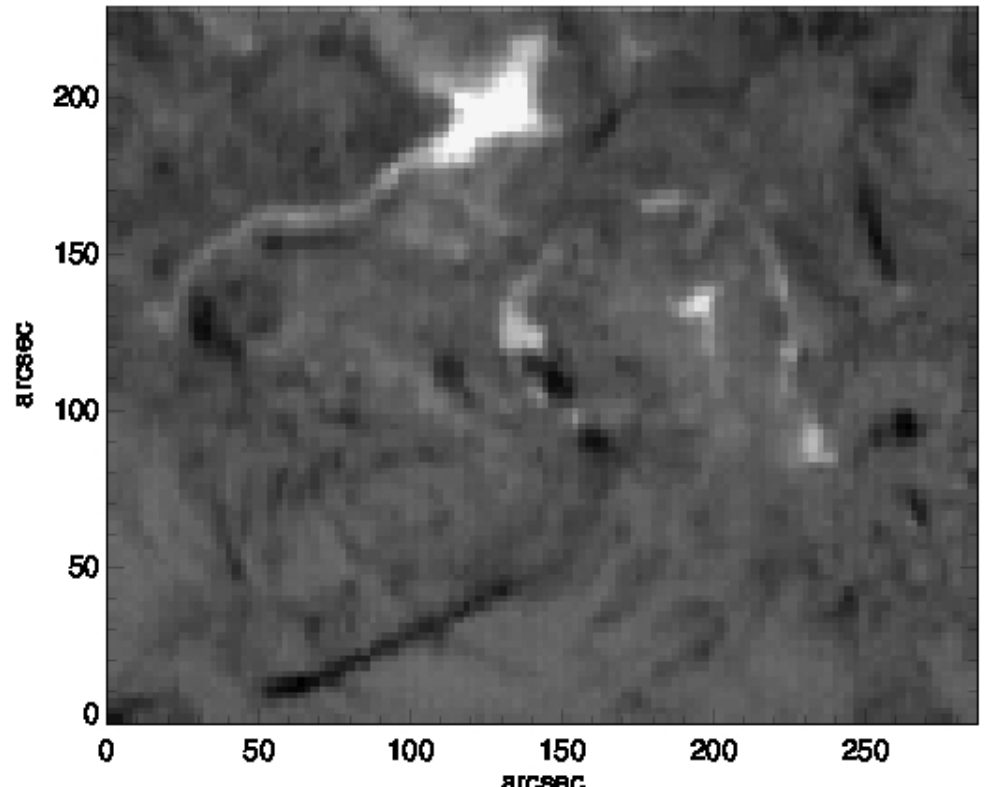
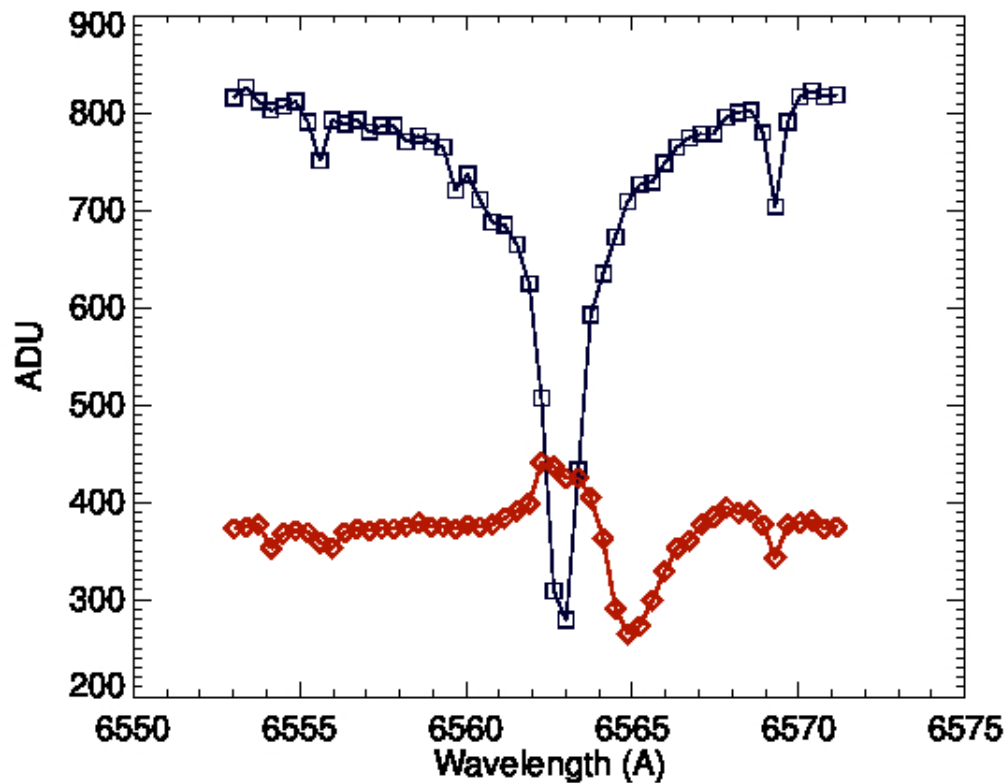
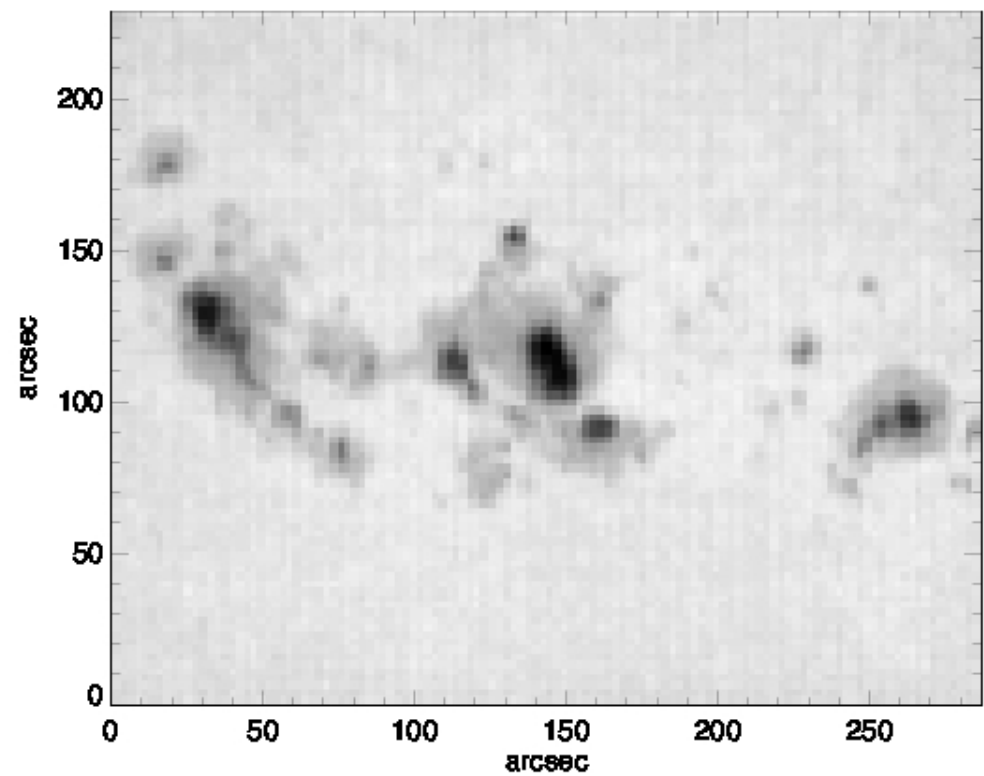


Fig. 3a. The response of the MCCD system to a HeNe laser beam at $\lambda 6328 \text{ \AA}$. We used the echelle grating (No. 2) with a 42 \mu m slit and a long exposure of 100 s. A Gaussian fit to the observed line core (solid line in the figure) gives a full width at half-max (FWHM) of 28 m\AA . This implies that the spectral resolving power $R = \lambda/\delta\lambda = 226000$.

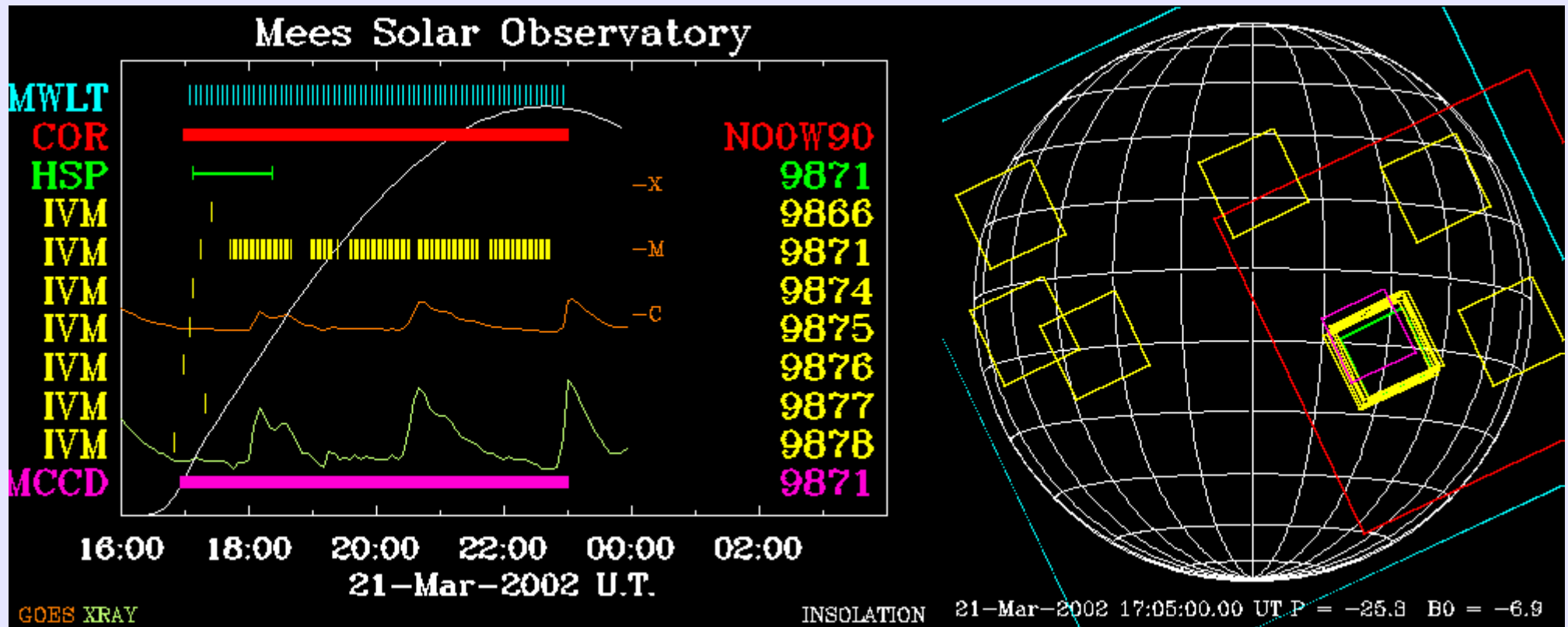
* If interested, I'll tell the story of my first PhD thesis topic.

H α “flare-mode” observing:

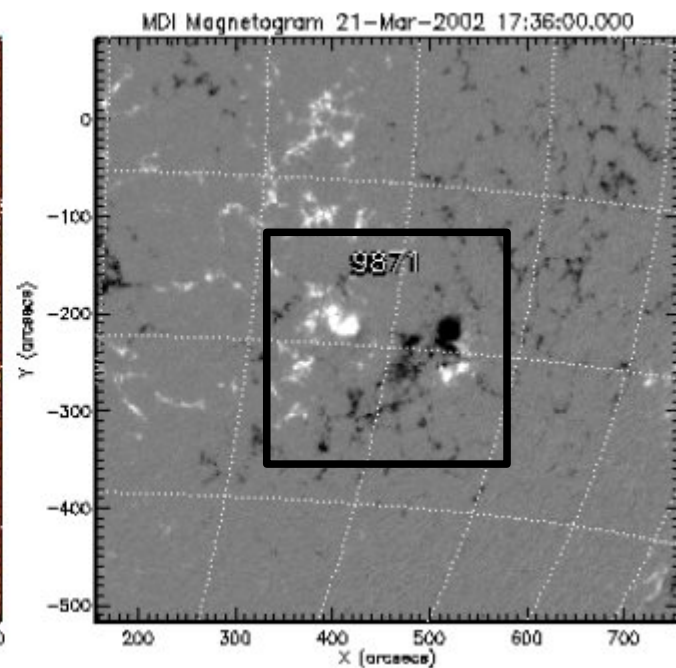
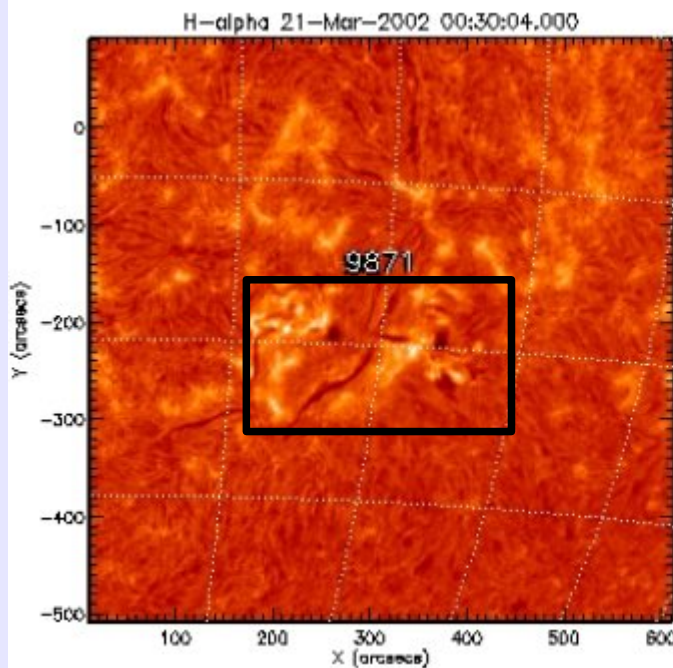
- H α \pm 9Å @0.375Å sampling (bin x4)
- 20 –30 sec cadence
- “Sit & Stare” at MaxMillennium or similarly coordinated target.



Example Day at MSO (including coordinated MCCCD, IVM observations)



*MCCD
approximate
FOV*



*IVM
approximate
FOV*

Present Status of MCCD Data:

- NWRA secured a small (!) NASA/HDEE* grant to rescue data from tape and make Level-1 data available to community.
 - Grant has been very screwed up \$\$- and timing-wise.
 - Data (42 boxes!) were delivered to NWRA in April 2016.
 - NWRA's software engineer has secured exabyte drives and a dedicated machine, and wrote scripts for data retrieval.
 - KD wrote preliminary flat-fielding scripts
 - Two summer students retrieved 1.5yr of data (2005, 2004)
- Data formats are almost finalized:
 - Level-0 (absolutely raw instrument-specific format)
 - Level-0.5 (FITS headers, file-type identified)
 - Level-1 (FITS headers, missing information filled in as available through automated scripts, WCS-compliant keywords, nominally processed (DC-subtracted, spatial flat-field).
 - TBD: Level-2 (spectral flat-field, jitter correction)

* Heliophysics Data Environment Enhancements

MCCD studies (already published) related to flares:

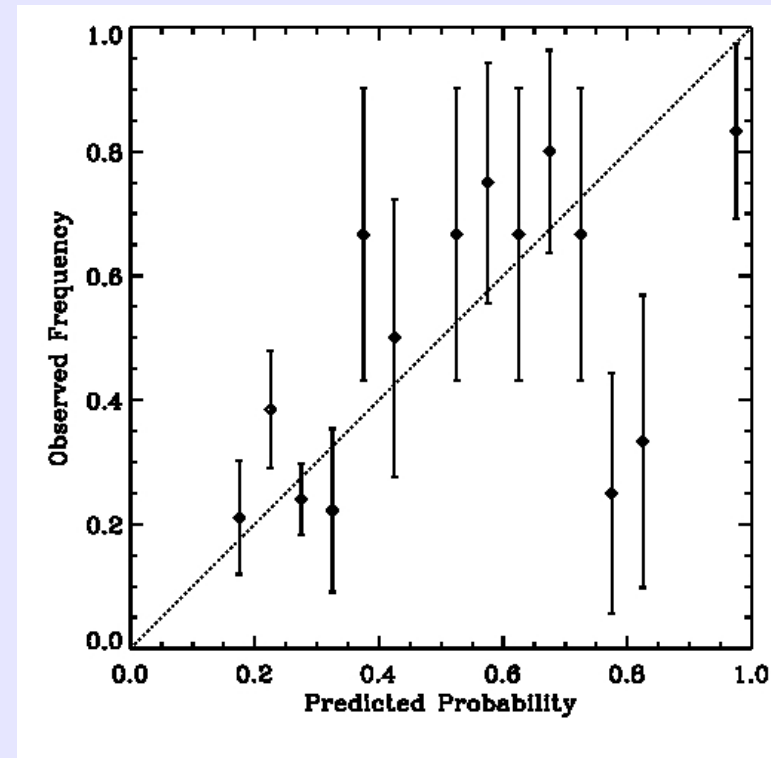
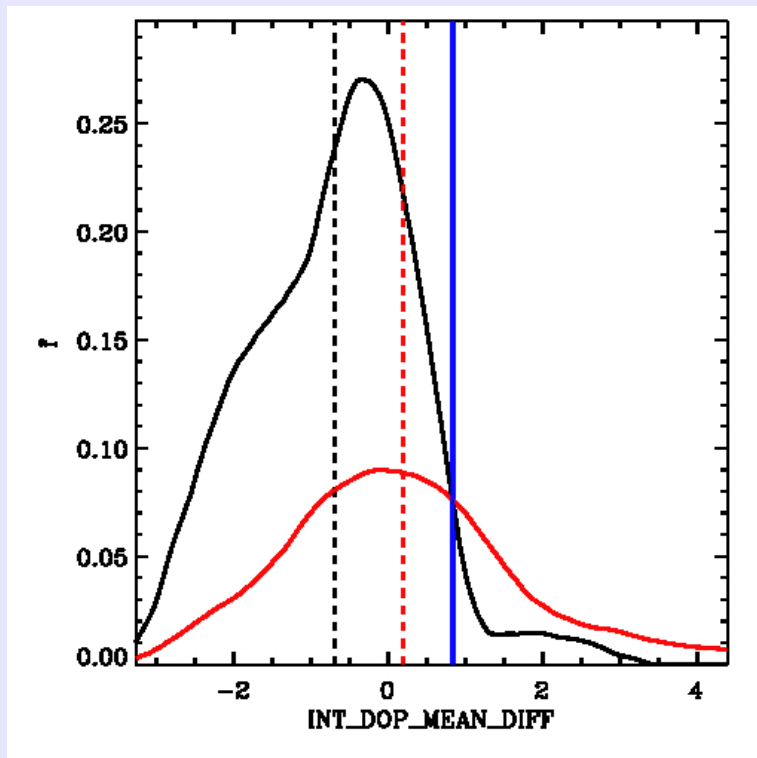
- Solar flare and chromospheric surge initiation and morphology
 - Canfield et al 1996; Leka et al 1996; van Driel-Gesztelyi et al 1996; Jibben & Canfield 2004.
- Solar flares and magnetic topology
 - Bagala et al 2000; Hahn et al 2005; Li et al 2005.
- Pre-flare activity including filament activation
 - Canfield & Reardon 1998; DesJardins & Canfield 2003; Li et al 2005.
- Flare-related particle acceleration
 - Metcalf et al 1992; Canfield et al 1992; de La Beaujardiere et al 1992; Canfield et al 1993; Leka et al 1993; de La Beaujardiere et al 1993.
- The physics of flaring chromospheres
 - Wuelser et al 1994.

Preliminary work on pre-flare signatures:

- 2016 Summer interns at NWRA (NSF/REU & NASA-funded)
- Parametrized H α spectral characteristics
 - Doppler shifts, line-depth, *etc.*
- MCCD data from 2004—2005
 - C1.0+ threshold for events
 - 0.5-hr long time-series analyzed for parametrizations.
- Super-posed epoch approach:
 - 39 events: 0.5hr ends with an event within 1hr after time-series ends.
 - 99 non-events: no event occurring within 12hr after time-series ends.
 - *In all cases*, no event was allowed within 6hr of time-series start time.

Preliminary work on pre-flare signatures:

- Sample Result (with cross-validation):
 - Brier: 0.12; Appleman (climatology reference): 0.18.
 - Crazy-small sample size,
 - Less rigorous event definition than needed.



Non-parametric 1-var DA results for H α spectral-based parameter. (Left) **quiet** and **flaring** NPDEs, with distribution means indicated; **DA boundary** is also shown. (Right) resulting reliability plot; large error bars due to small sample size.

MCCD data also good for:

- Further study of filaments
 - formation, energization, eruption initiation
- Further study of flares
 - Kinetic energy release
 - chromospheric heating
- NLFFF boundary constraints
 - *in conjunction with IVM data*
- lots more, I'm sure....*especially* if large database needed.

Reality / Still Needed

- Needed: code development for:
 - better spectral-flat-fields
 - automated AR-identification and improved coordinates
 - better handling of data gaps
 - *post-facto* image stabilization
 - website hosting
- Needed: time for:
 - data rescue
 - cataloging
- Reality:
 - next \$\$ increment summer 2017
 - have applied for additional \$\$; if selected, funding about same time

Reality / Still Needed

- Needed: code development for:

- better spectral-flat-fields
- automated AR-identification and improved coordinates
- better handling of data gaps
- *post-facto* image stabilization
- website hosting

Have experience & expertise,
just need time/money

- Needed: time for:

- data rescue
- cataloging

- Reality:

- next \$\$ increment summer 2017
- have applied for additional \$\$; if selected, funding about same time

Blame NASA. This has been an amazing
study in bad beaurocrasy. I am trying to
have patience....

Wish us luck!

Reality / Still Needed

- Needed: code development for:

- better spectral-flat-fields
- automated AR-identification and improved coordinates
- better handling of data gaps
- *post-facto* image stabilization
- website hosting

Have experience & expertise,
just need time/money

- Needed: time for:

- data rescue
- cataloging

- Reality:

- next \$\$ increment summer 2017
- have applied for additional \$\$; if selected, funding about same time

Blame NASA. This has been an amazing
study in bad beaurocrasy. I am trying to
have patience....

Wish us luck!

- In the meantime:

- Sample Data at: www.cora.nwra.com/~leka/Projects/MCCD/
(see README there)
- *Funded* students/postdocs who would like to collaborate (and help rescue data, etc.) and learn about imaging spectroscopy and data handling in the context of flare prediction, please contact KD.