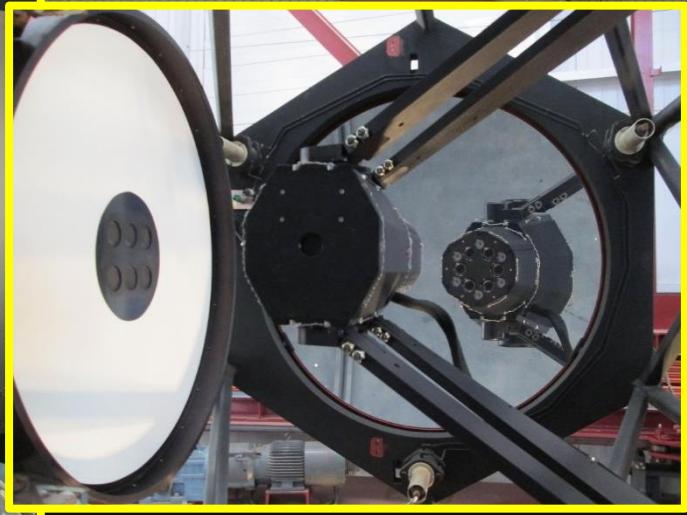
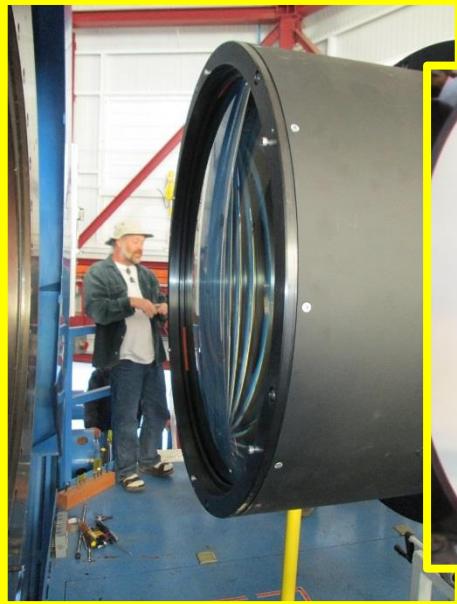
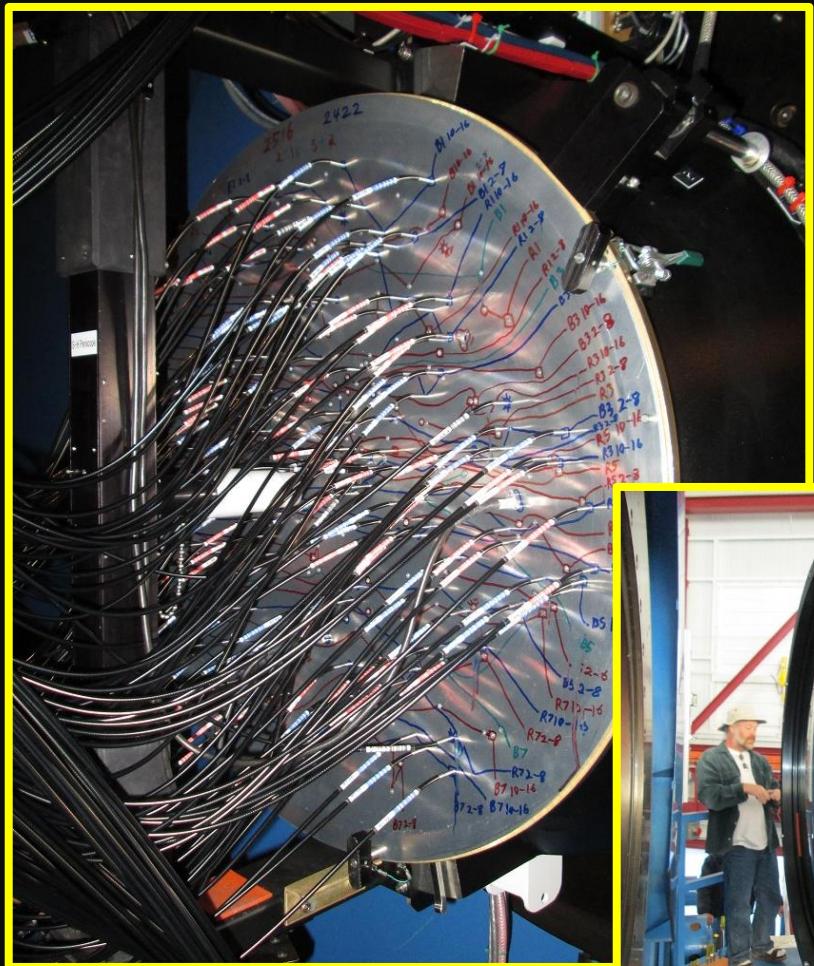


M2FS: The Michigan/Magellan Fiber System: Data Reduction Overview



M2FS: Terminology

Data are defined by:

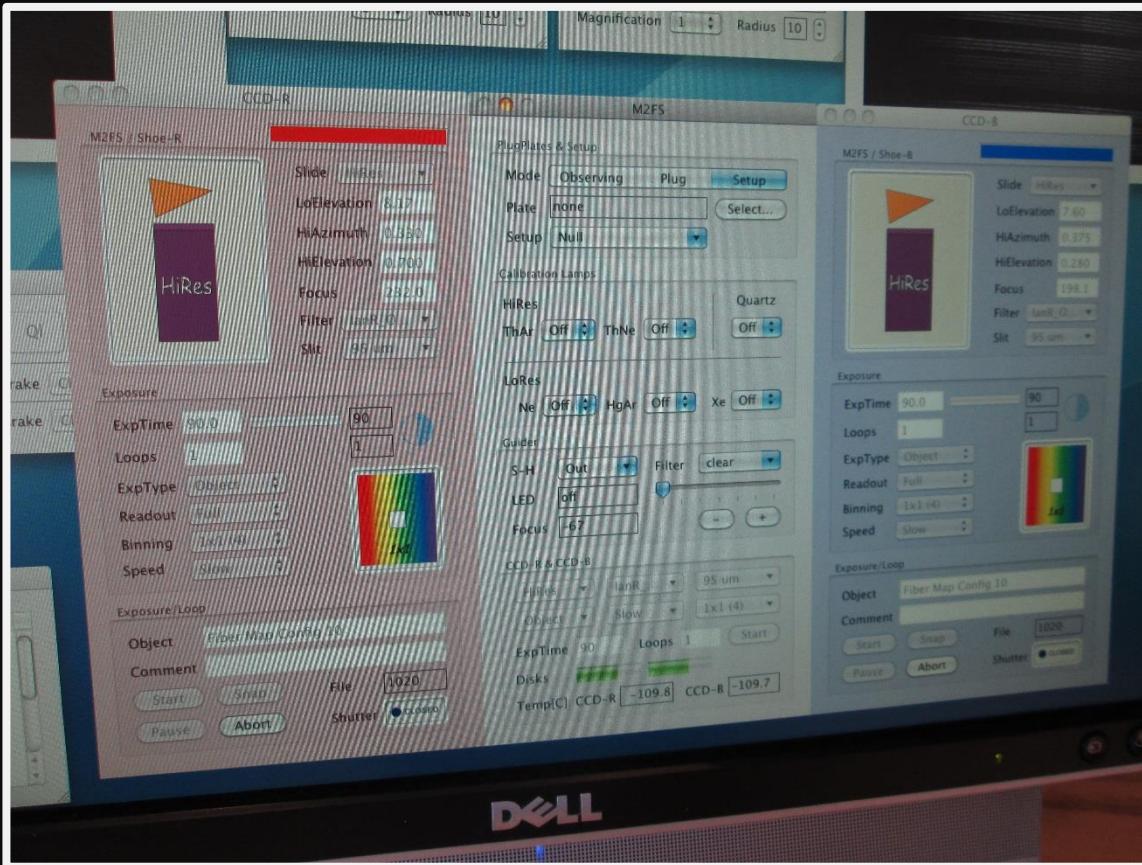
- Field — The set of targets observed in a single observation/set of exposures.
- Plate — The physical plate on which the field is drilled.
- Configuration — The full set of instrument parameters that are used to carry out an observation.
- Setup — The full combination of field, plate, and configuration used for a specific set of observations.

M2FS: Configurations

Configurations are defined by:

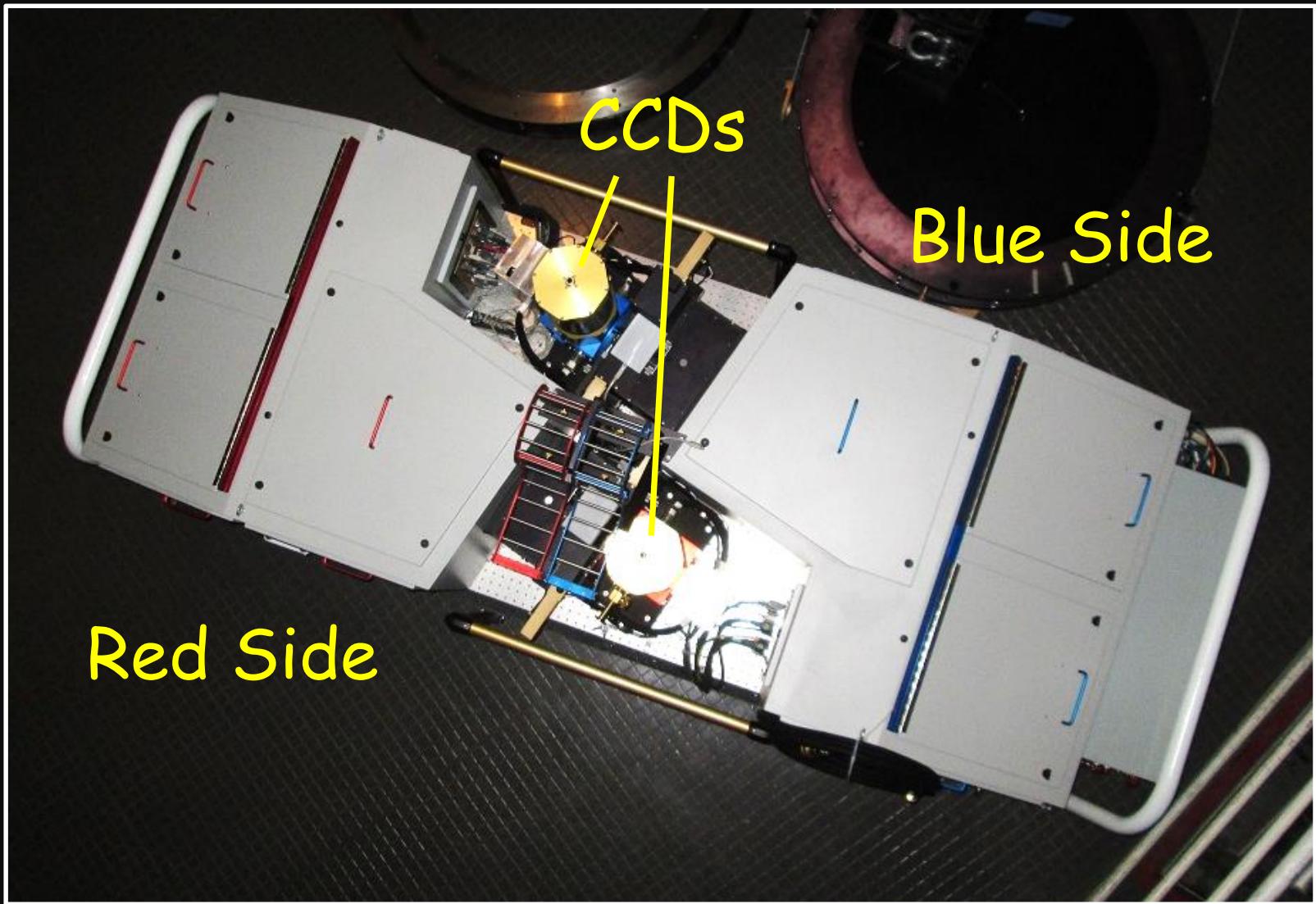
- MSpec Side — B or R spectrograph.
- Resolution — HiRes (Echelle + cross-disperter), or LoRes (Standard/Echellette grating)
- Grating Angles — El/Az (HiRes) or El (LoRes)
- Blocking Filters — Isolate orders/BK7 in LoRes
- Focus — B/R separate; depends slightly on temperature.
- Fiber Slits — Wide open to 45-microns; 8 pos.
- CCD binning — Somewhat complicated, but many options available; depend on amplifiers.
- Readout Details — Speed; full/subraster.

M2FS: Basics



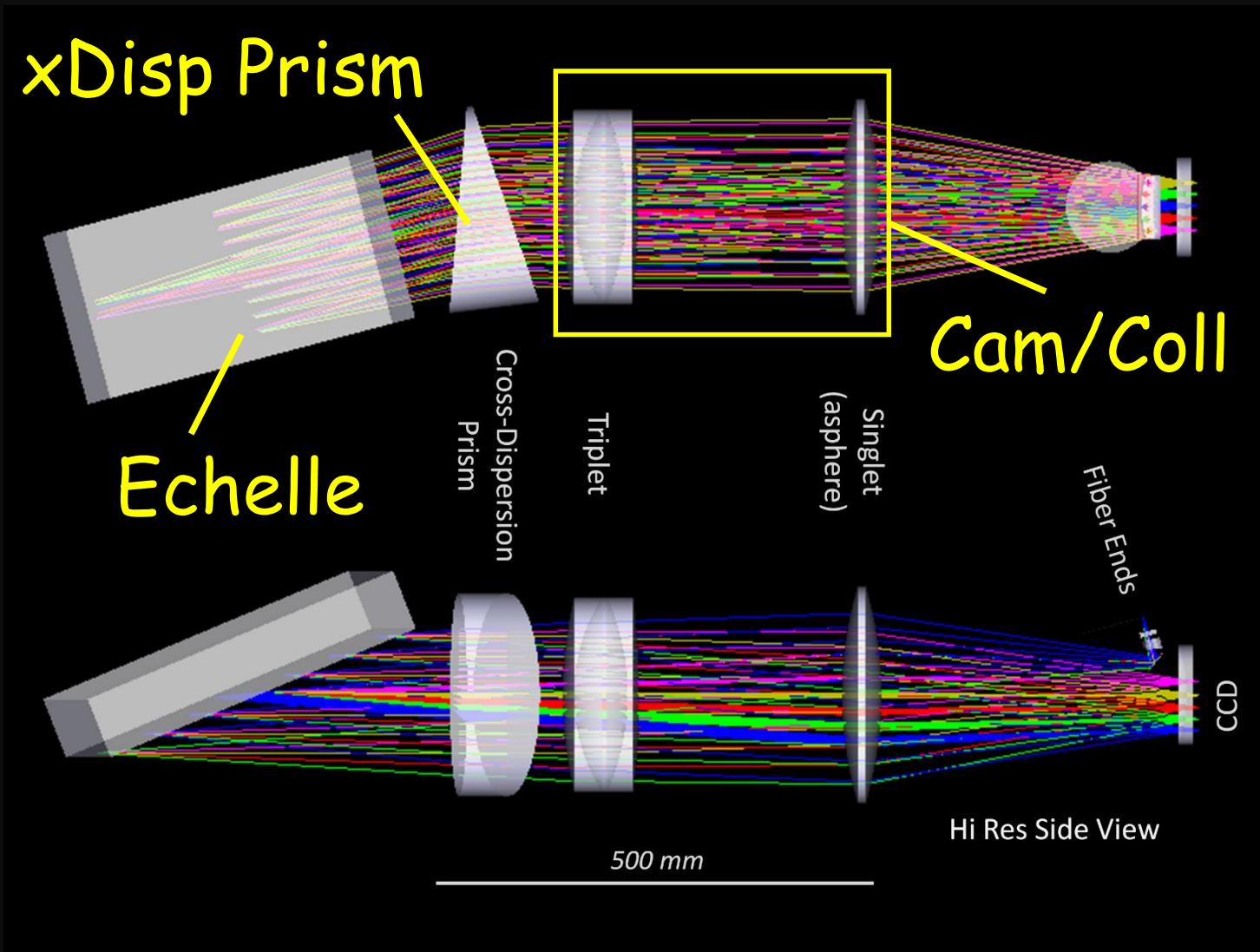
Users select configuration variables via instrument GUI.

Parameters can be saved and read from files.

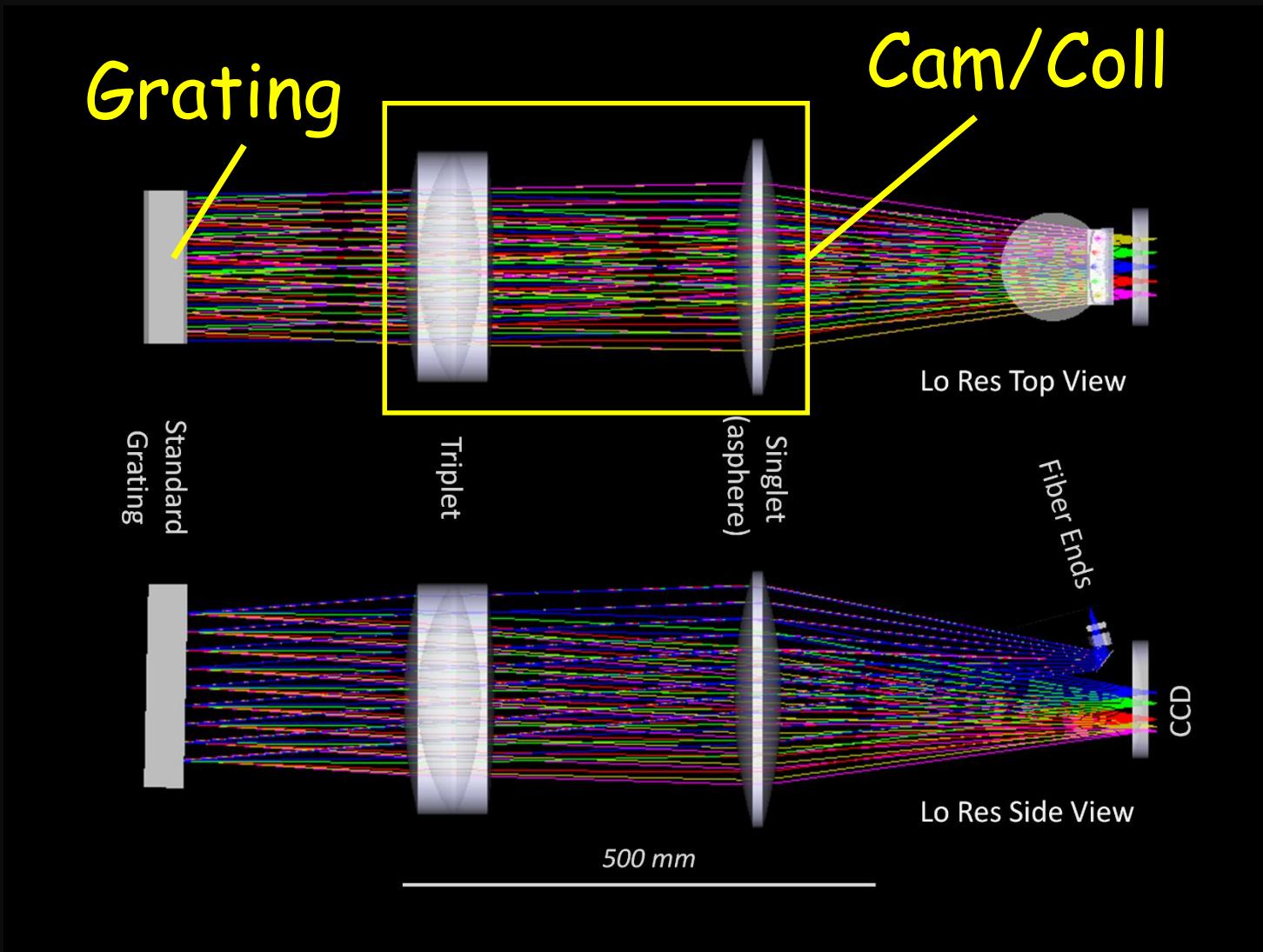


Identical Channels; names are relics.

M2FS Optical Layout: Theory/HiRes



M2FS Optical Layout: Theory/LoRes



M2FS: Configurations

Through commissioning (Aug 2013) and two science runs (Nov 2013 and Feb 2014), we now have 15 configurations defined:

- Config 1 – Mgb filter; HiRes; 2x2; 180 mic slit; grating angles.
- Config 5b – Hot Jupiter filter; HiRes; 1x1; 45 mic slit; grating angles.
- Config 9 – BK-7; 3700-5700A; LoRes; 2x2; 180 mic slit; grating angle.
- Config 12 – Halpha/Li filter; HiRes; 1x2; 75 mic slit; grating angles.

M2FS: Resources to Users. I.

- Data logs (*active*) – Primary source of information for images. IMAGE HEADERS MAY NOT ALWAYS BE RELIABLE.
- Data repository (*active*) – Available at
<https://m2fs.astro.lsa.umich.edu/data/>
(m2fs/m2fsdata)
- Configuration parameter files – Saved at the telescope; available if/as needed.
- Data reduction scripts (*not active*) – TBD

M2FS: Data Characteristics. I.

- Data format – Single extension FITS.
Multi-extension possible if demand is high.
- Amplifiers – Currently support 1, 2 or 4-amp, readouts. At telescope, files are saved as

fNNNNcM.fits

where f=r,b, N=frame number, M=amp.

- Data Directories – Standard practice is to sort by ut date: /utYYYYMMDD
- Example – /feb2014/ut20140218/b0198c2.fits

M2FS: Data Headers

- TCS Information – Telescope position, time of observation, orientation of dome, etc. **RELIABLE**.
- Instrument Status – Environment temps, *CCD* temps, *CCD* readout details, configuration parameters, etc. **RELIABLE**.
- Field/Plate Information – Name of plate, name of target field, full fiber cross indexing and information with target ids. **NOT YET RELIABLE**. Even when information is properly entered, fiber status may be wrong. Always check log.

```

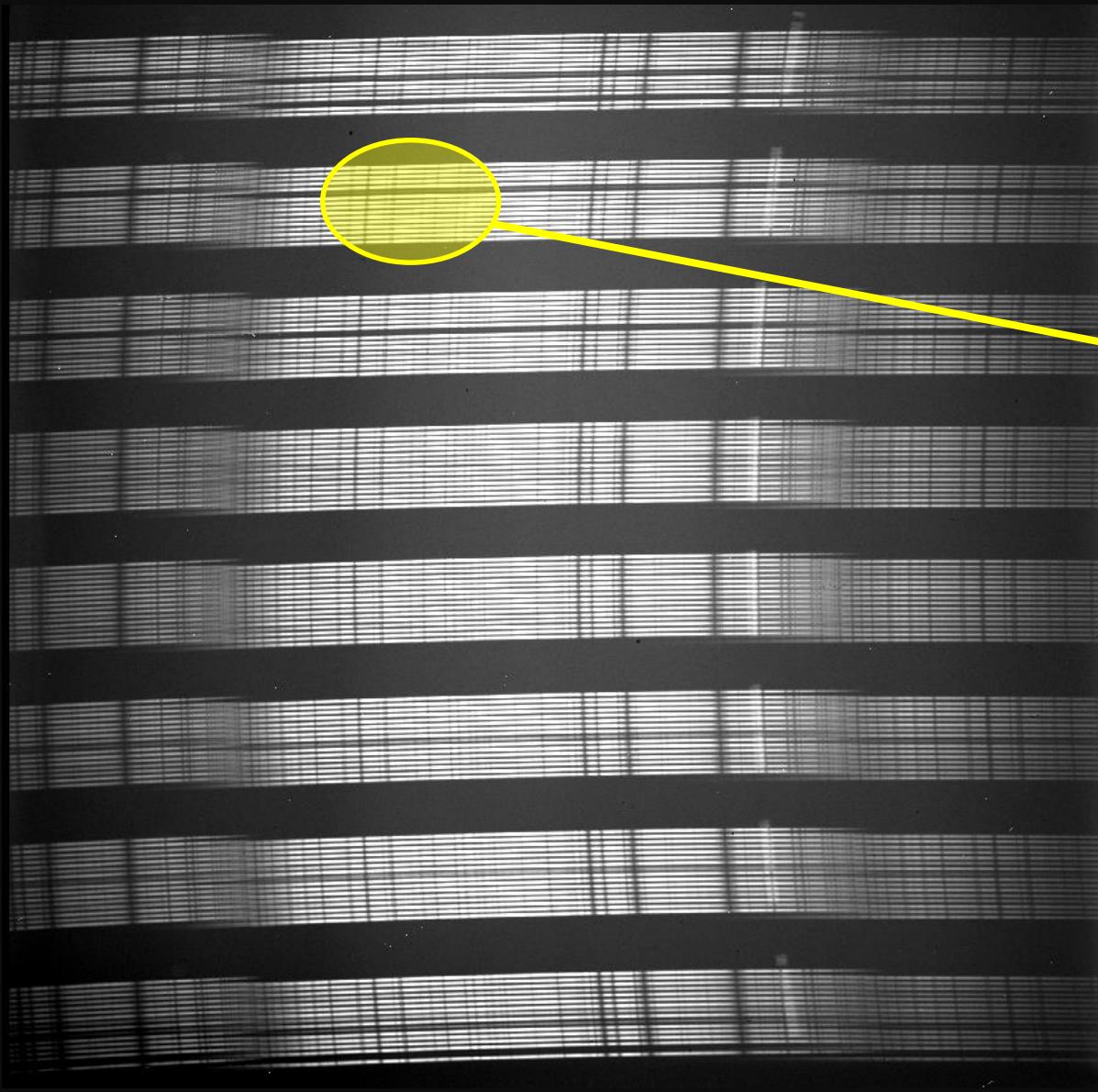
ROTANGLE=          172.80      / rotator offset angle
TEL-AZIM=         313.7       / telescope azimuth
TEL-ELEV=          65.5       / telescope elevation
T-DOME =           16.5       / dome temperature [C]
T-CELL =           14.4       / primary cell temperature [C]
T-TRUSS =          11.4       / telescope truss temperature [C]
WX-TEMP =          13.9       / weather station temperature [C]
FILENAME= 'r0713c1'
COMMENT =          /
EXPTYPE = 'Object'
EXPTIME =        2400.000    / exposure time
NLOOPS =            1          / # of loops per sequence
LOOP =              1          / # within this sequence
BINNING = '2x2'
SPEED = 'Slow'
NOVERSNC=          128        / overscan pixels
NBIAISLMS=         128        / bias lines
BIASSEC = '[1025:1152,1029:1156]' / NOAO: bias section
DATASEC = '[1:1024,1:1028]'     / NOAO: data section
TRIMSEC = '[1:1024,1:1028]'     / NOAO: trim section
SUBRASTR= 'none'             / full frame
TEMPCCD =        -110.0      / CCD temperature [C]
SHOE = 'R'
SLIDE = 'HiRes'
SLIDEENC=        273.0      / slide encoder
SLIDESTP=        4200       / slide step
LO-ELEV = '11.1501'
HI-AZIM = '-0.09998'
HI-ELEV = '0.99999'
FOCUS =          228.1      / step= 2281
FILTER = 'Mgb_Rev2'
SLITNAME= '180 um'
SLIT1 = '180 um'
SLIT2 = '180 um'
SLIT3 = '180 um'
SLIT4 = '180 um'
SLIT5 = '180 um'
SLIT6 = '180 um'
SLIT7 = '180 um'
SLIT8 = '180 um'
FF-THNE =          0          / lamp level (0=off)
FF-THAR =          0          / lamp level (0=off)
FF-NE =            0          / lamp level (0=off)
FF-HGAR =          0          / lamp level (0=off)
FF-XE =            0          / lamp level (0=off)
FF-QRTZ =          0          / lamp level (0=off)
PLATE = 'sextanscentercrater'
PLATESTP= 'Setup 4'
PLATEPNAME= 'plate setup'
PLATEPNAME= 'SH_Periscope'
TEMP01 =          16.200     / Cradle_R
TEMP02 =          16.875     / Cradle_B
TEMP03 =          17.312     / Echelle_R
TEMP04 =          15.562     / Echelle_B
TEMP05 =          16.375     / Prism_R
TEMP06 =          15.688     / Prism_B
TEMP07 =          16.438     / LoResGrating_R
TEMP08 =          15.312     / LoResGrating_B
TEMP09 =          16.125     / LoResGrating_B
SOFTWARE= 'Version 1.1 (1.0100) (Feb 13 2014, 11:00:58)'
FITSVERS= '1.1'      / FITS header version
FIBER101= 'inactive' / FID=125 Fab=24/1 C/H=02/01
FIBER102= 'inactive' / FID=422 Fab=24/2 C/H=02/02
FIBER103= 'inactive' / FID=22 Fab=25/10 C/H=02/03
FIBER104= 'inactive' / FID=434 Fab=24/4 C/H=02/04
FIBER105= 'inactive' / FID=123 Fab=24/5 C/H=02/05
FIBER106= 'inactive' / FID=51 Fab=24/6 C/H=02/06
FIBER107= 'inactive' / FID=430 Fab=24/7 C/H=02/07
FIBER108= 'inactive' / FID=250 Fab=24/8 C/H=02/08
FIBER109= '11:36:34.40_-11:01:56.9' / FID=272 Fab=25/3 C/H=02/09
FIBER110= '11:36:35.74_-11:01:54.0' / FID=214 Fab=25/2 C/H=02/10
FIBER111= '11:36:21.48_-11:01:25.8' / FID=128 Fab=26/8 C/H=02/11
FIBER112= '11:36:28.64_-10:58:45.1' / FID=158 Fab=26/1 C/H=02/12
FIBER113= '11:36:15.48_-10:58:30.1' / FID=40 Fab=24/13 C/H=02/13
FIBER114= '11:36:17.28_-10:58:18.2' / FID=155 Fab=26/6 C/H=02/14
FIBER115= '11:36:24.12_-10:57:11.8' / FID=428 Fab=24/15 C/H=02/15
FIBER116= '11:36:15.31_-10:56:46.3' / FID=433 Fab=24/16 C/H=02/16
FIBER201= '11:36:56.38_-10:47:1.4' / FID=368 Fab=18/1 C/H=04/01
FIBER202= 'sky'                  / FID=366 Fab=18/2 C/H=04/02
FIBER203= '11:37:4.64_-10:52:30.4' / FID=13 Fab=26/10 C/H=04/03

```

M2FS: Data Headers

- Exposure info
- CCD sampling
- Slit assignments
- System temps
- Fiber mapping

M2FS: Fiber IDs

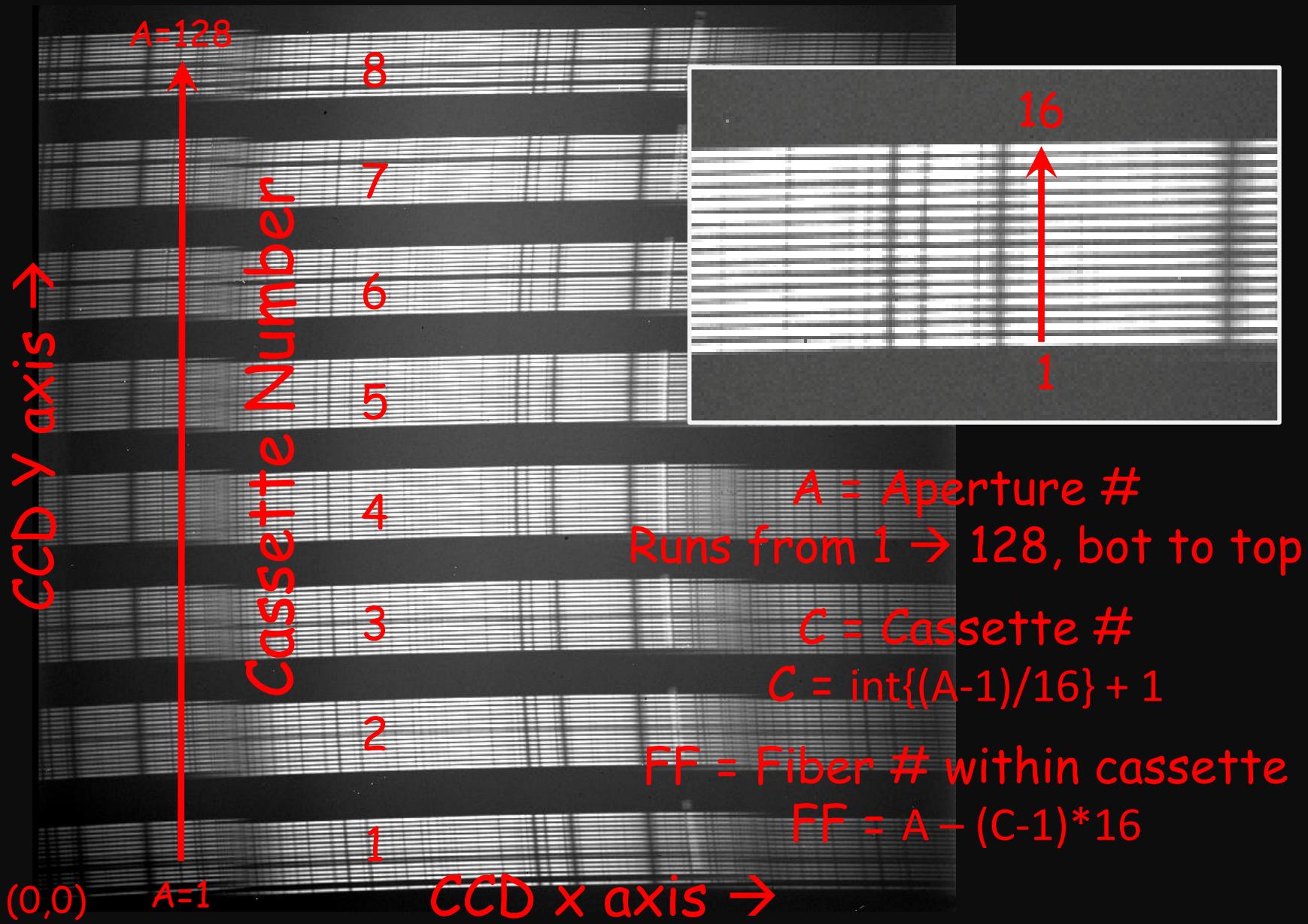


Each group of 16 fibers represents a 'cassette' or 'tetris'.

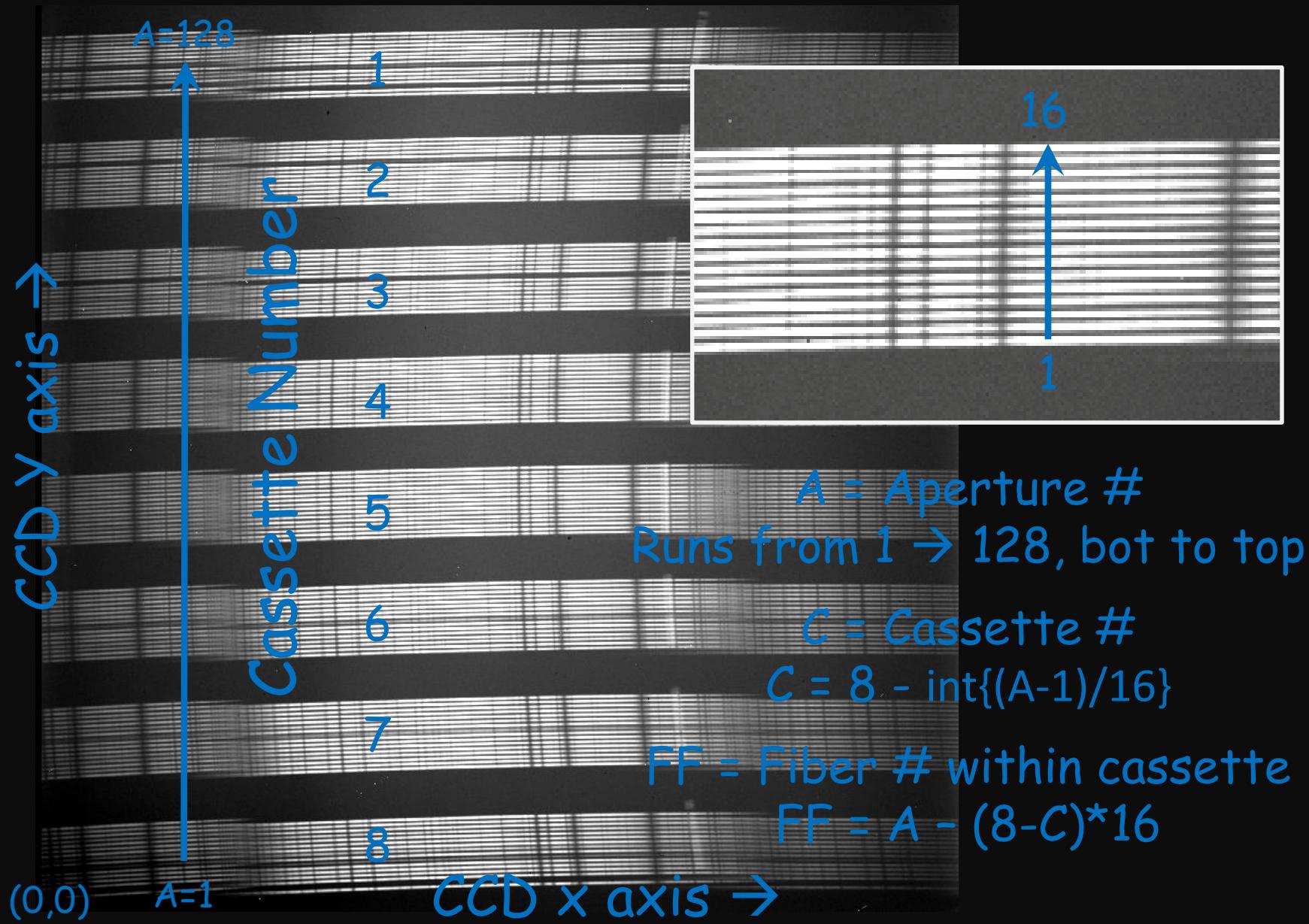
The B and R side CCDs have different mappings of cassette/tetris and fiber numbers.

Fibers designated as $SC\text{-}FF$ where S =‘side’ (R or B), C =Cassette #, FF =Fiber # in cassette (2 digit)

M2FS: Fiber IDs RED SIDE



M2FS: Fiber IDs BLUE SIDE

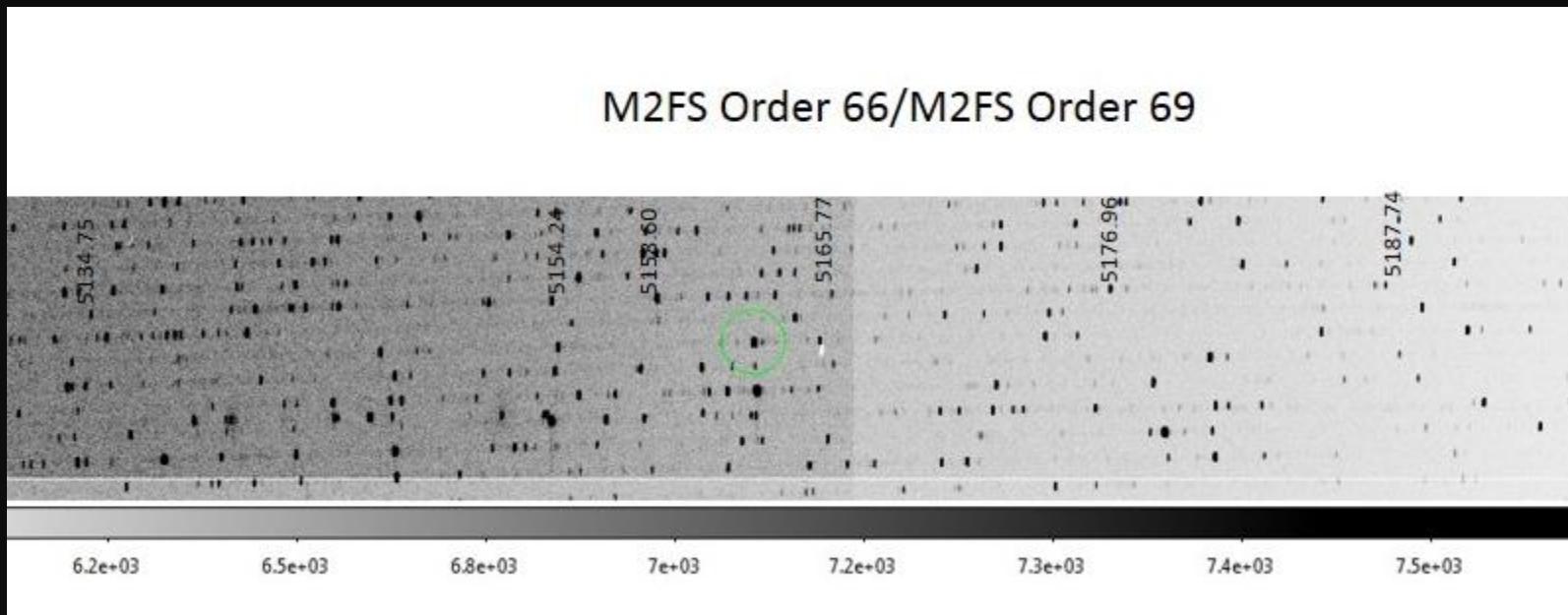


M2FS: Resources to Users. II.

- 'Fiber Maps' — Available for all configurations for a given run and specified in logs. Consist of daytime images with all fibers plugged for given configuration. Used to define extraction parameters. Multiple maps for multi-order configurations. Part of data archive.
- Plate Files — Separate lists for plates that detail all actual targets observed. Available on request. To be added to archive.
- Calibration Data — Typically obtain appropriate arcs, associated quartz exposures, bias sequences, twilights as standard part of observations. In data archive.

M2FS: Resources to Users. II.

- Arc Finding Charts – Available on request for some orders. On request and to be supplemented by users. Also MIKE ThAr atlas can be of use. LoRes atlases not available yet.



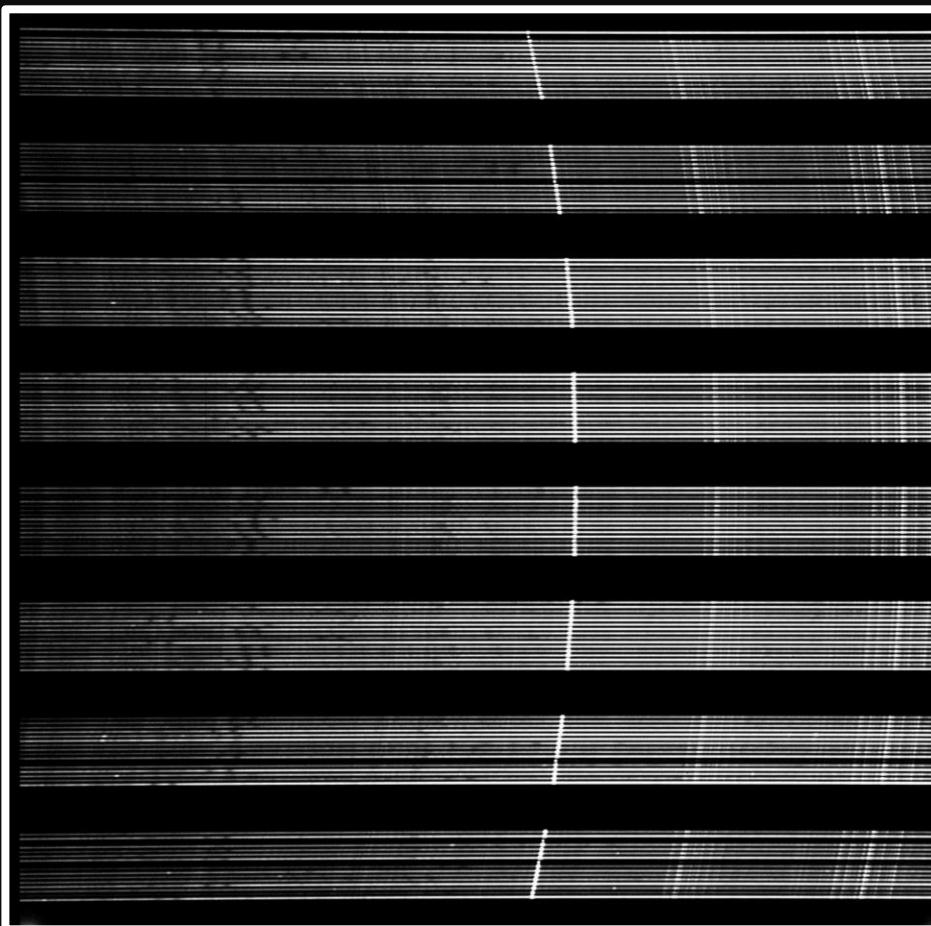
M2FS: Data Characteristics. II.

- 2x2 binning; HiRes; Single order per target.



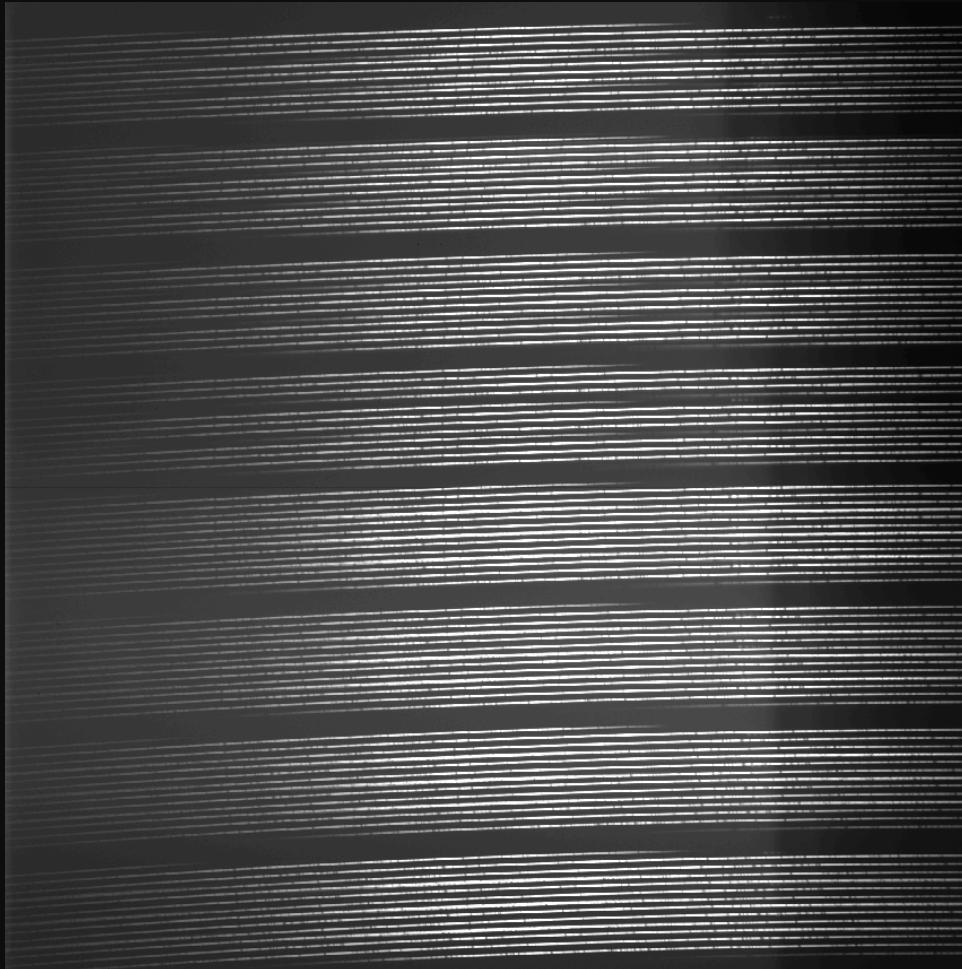
M2FS: Data Characteristics. II.

- 2x2 binning; LoRes (always single order per target).



M2FS: Data Characteristics. II.

- 1x2 binning; HiRes; Four orders per target.



M2FS: Data Reduction: Overview

- IRAF based processes and Python routines have been developed by MM and JB
- Simple command lists available for one-order, HiRes configurations (Mgb and CaT) from MM. Actual IRAF scripts under development. User repository for appropriate software to be developed as demand/availability dictate.
- Limited documentation.
- Examples here are all **IRAF-based** and are meant to illustrate key steps.

M2FS: Data Reduction: Overview

- Process raw images – Line overscan correction (`ccdproc`).



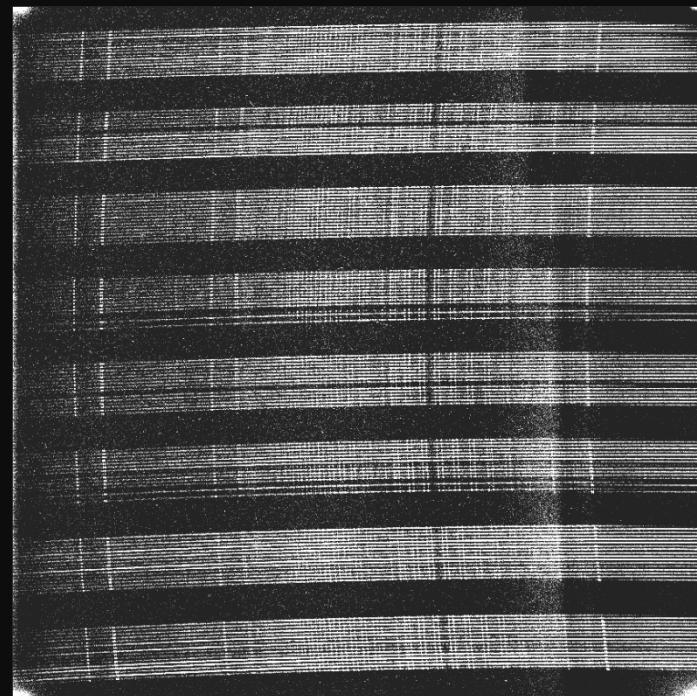
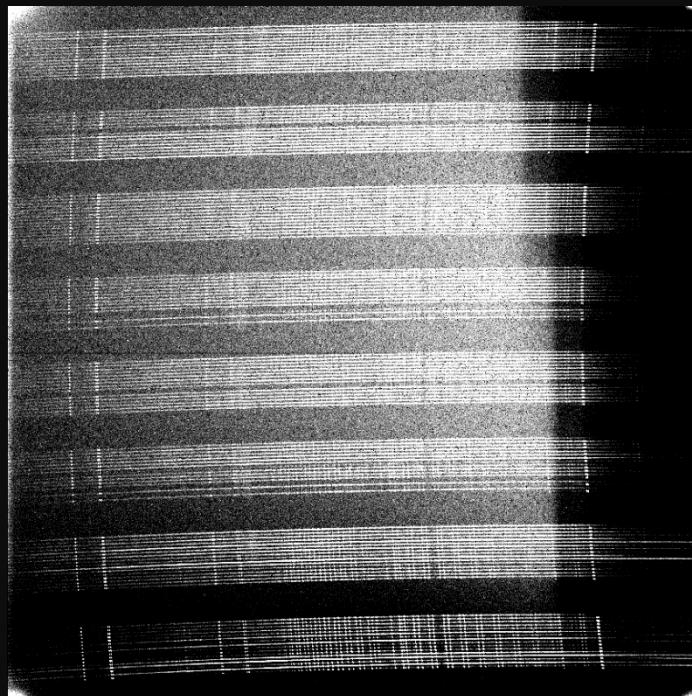
M2FS: Data Reduction: Overview

- Pack images – As needed depending on amplifier/binning choices. Results in single 2-D images with c1 header. (`imcreate`, `imcopy`)



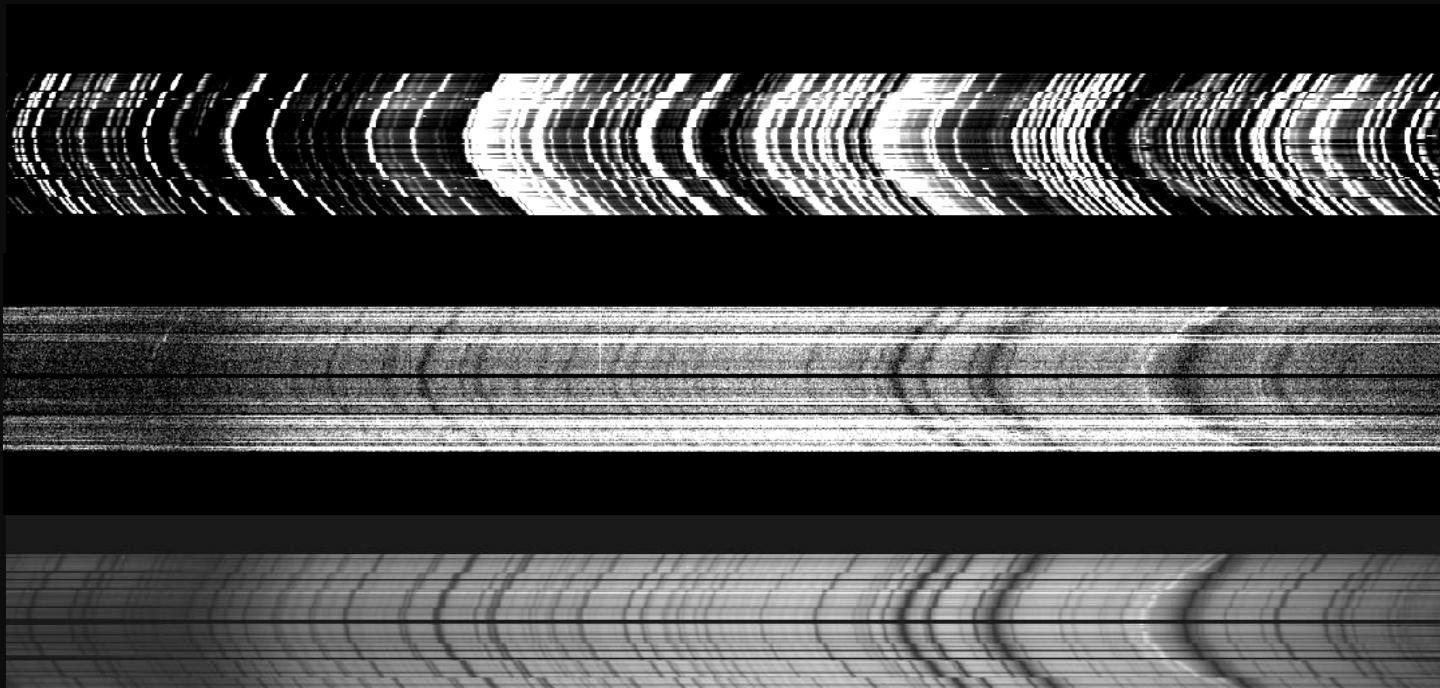
M2FS: Data Reduction: Overview

- Scattered light correction – As desired. Scattered light depends on spectrograph, and distribution of target brightnesses. Best practices still in development. ([imsurfit](#))



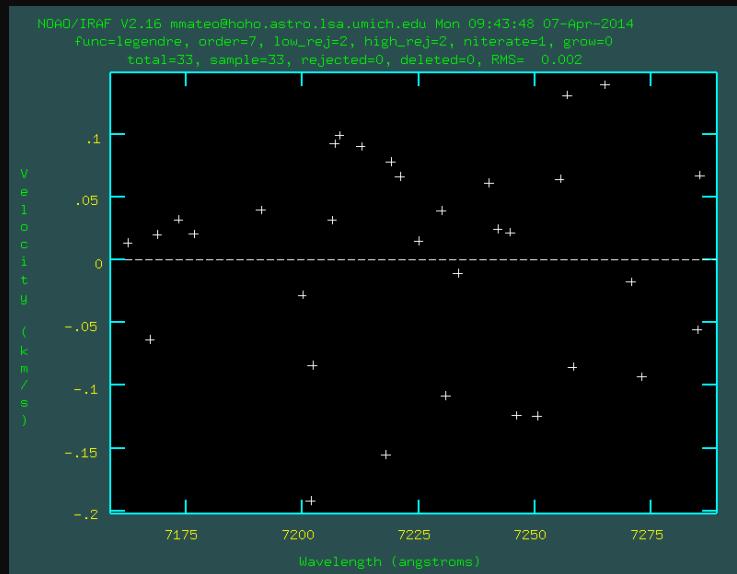
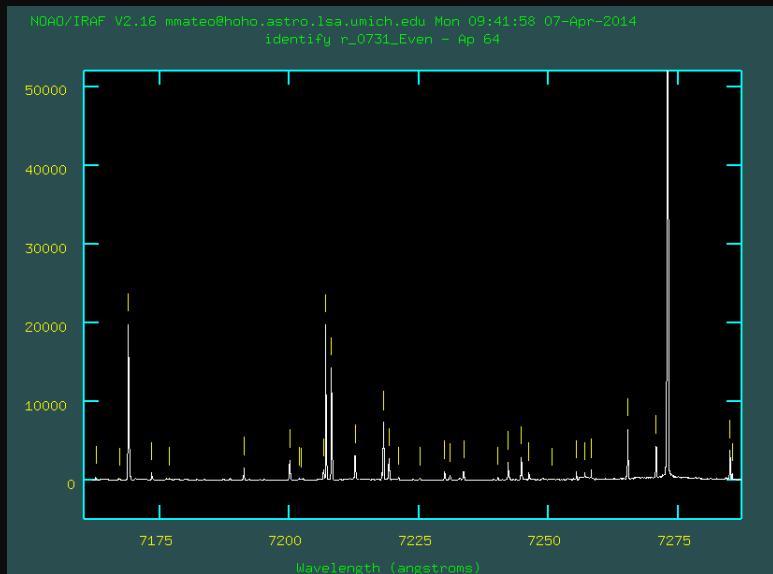
M2FS: Data Reduction: Overview

- Tracing orders — (1) Trace appropriate fiber maps for all N fibers for given configuration. (2) Apply trace to data directly or using 'local' quartz images as desired. (3) Apply to arcs and any other calibration data/standards. (apall)



M2FS: Data Reduction: Overview

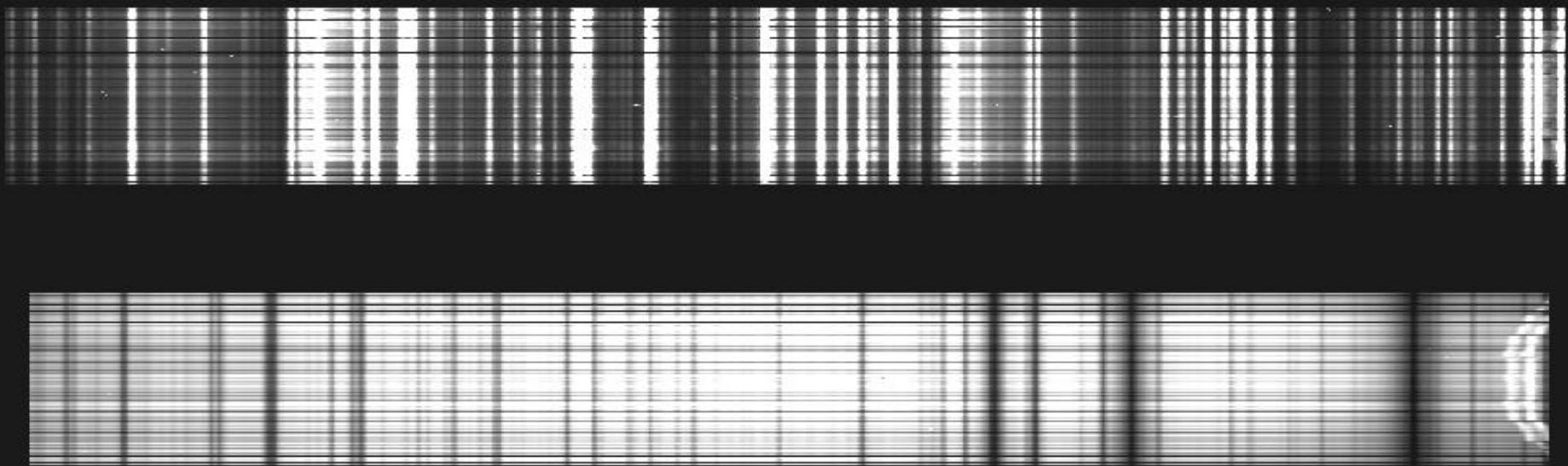
- Identify arc lines – Determine pix-lambda transformation. (identify, reidentify)



HiRes rms ~ 100-300 m/s; LoRes ~ 1 km/s

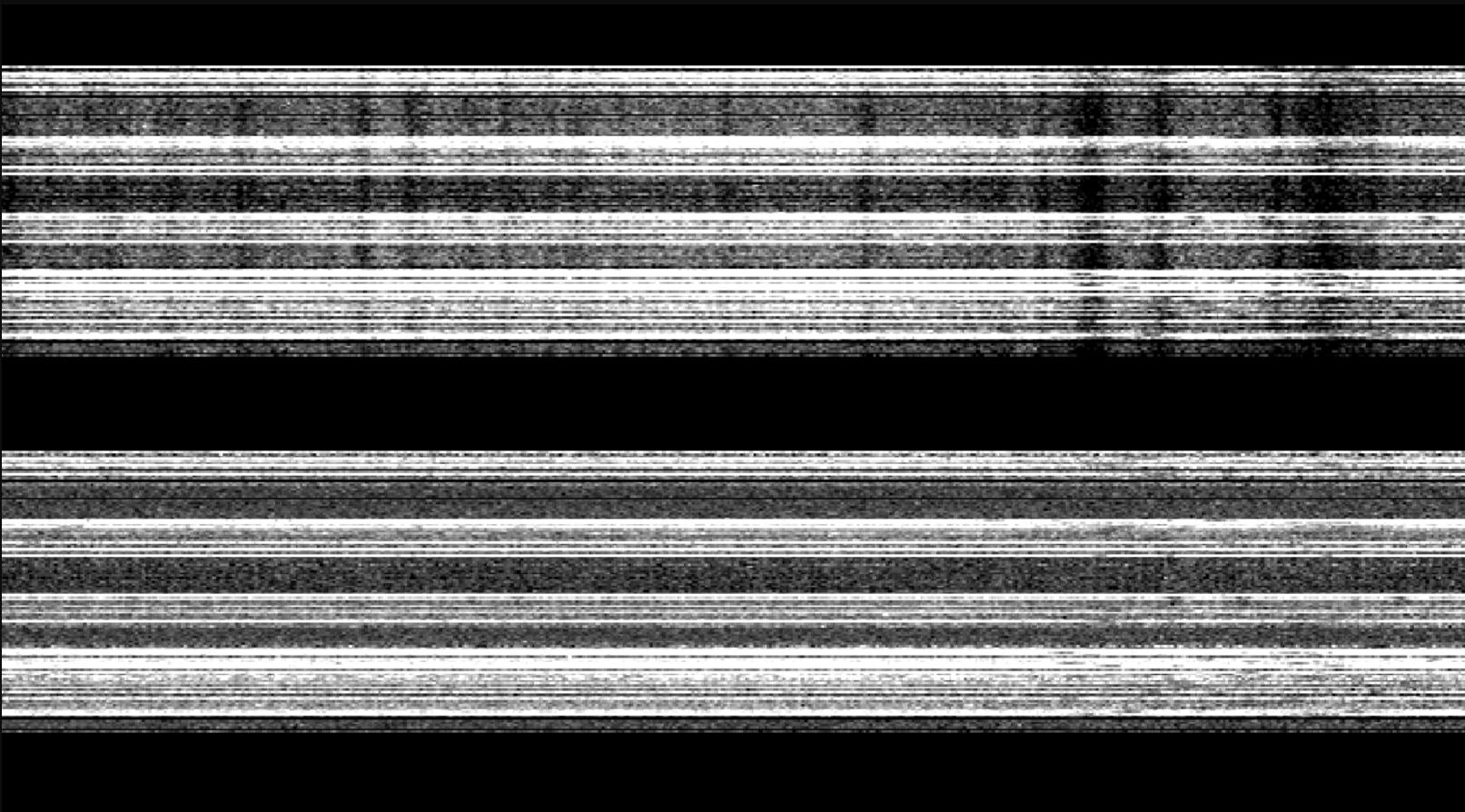
M2FS: Data Reduction: Overview

- Dispersion correct data – Apply dispersion correction to data as desired. Can either rebin data or simply place dispersion info in image headers for each fiber/aperture. (`refspec`, `dispcor`)



M2FS: Data Reduction: Overview

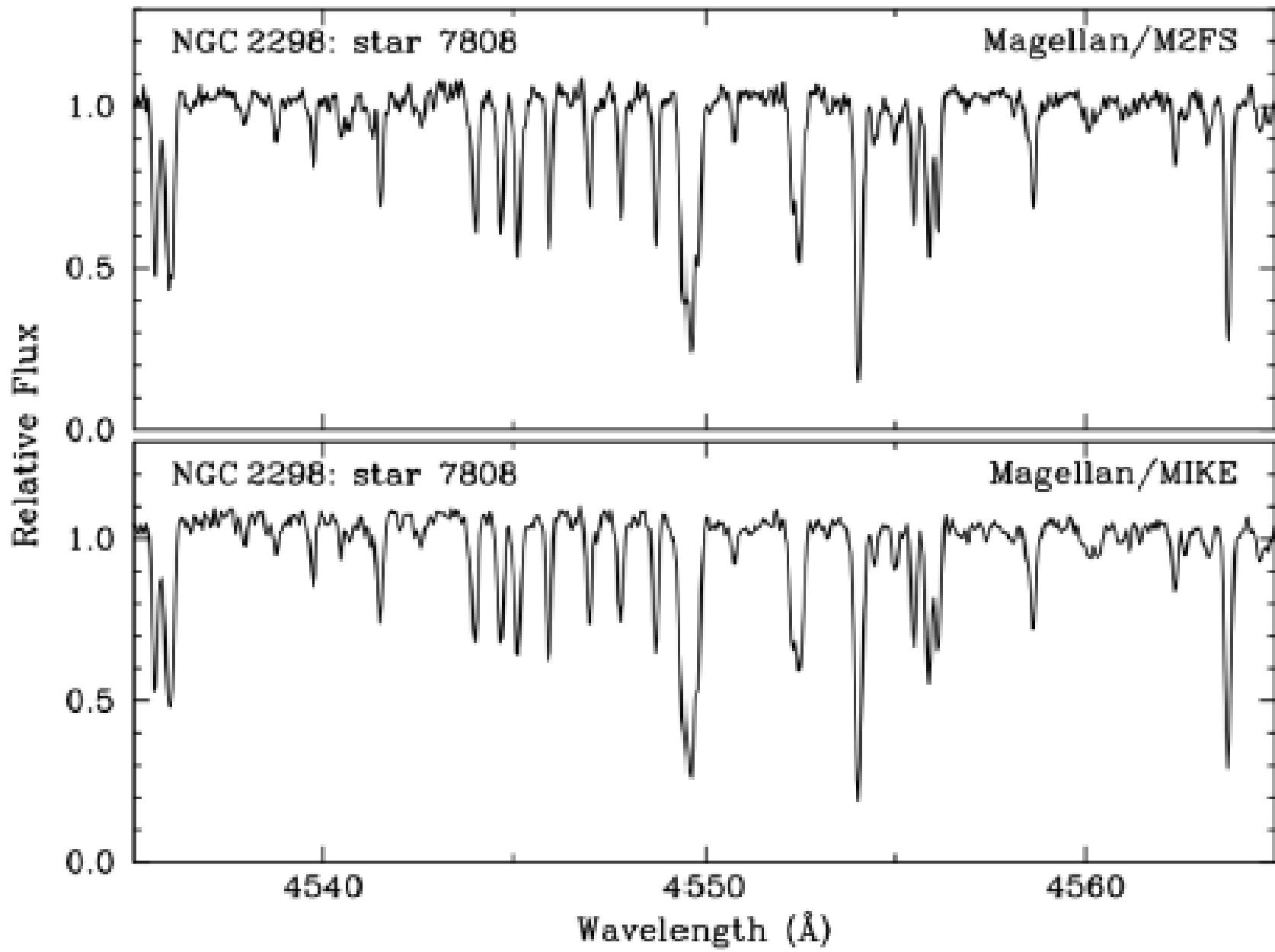
- Fiber corrections/Sky Subtraction – Remove fiber throughput variations. Remove average sky background



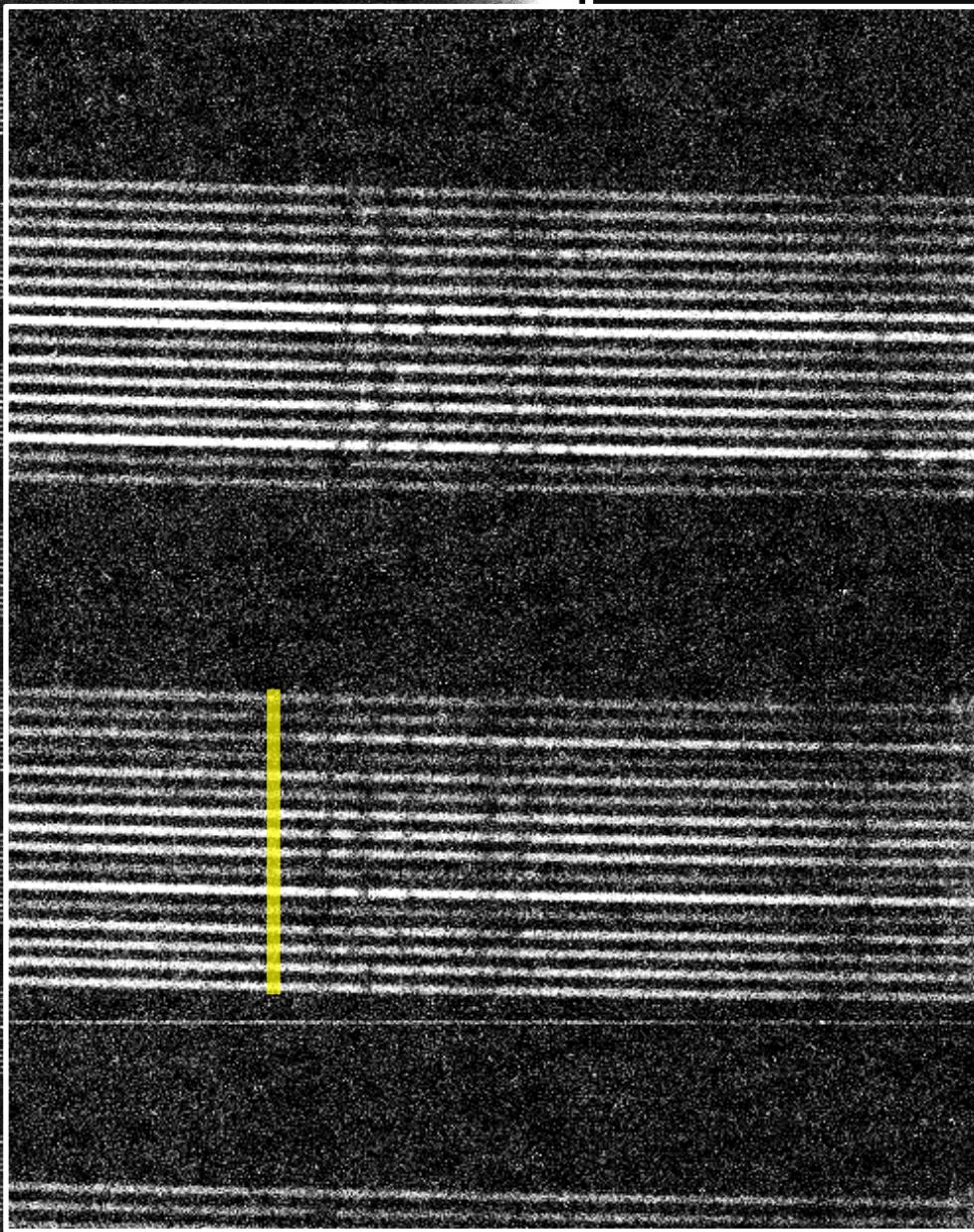
M2FS: Data Reduction: Comments

- Good velocity precision – Achieving 2-1% of resolution element at even low S/N
- Flat fielding – Details still to be worked out
- Web pages – Volunteers would be welcome!
- At your service for help, advice, additional data as needed.

M2FS: Data Reduction: Random Samples of Preliminary Results

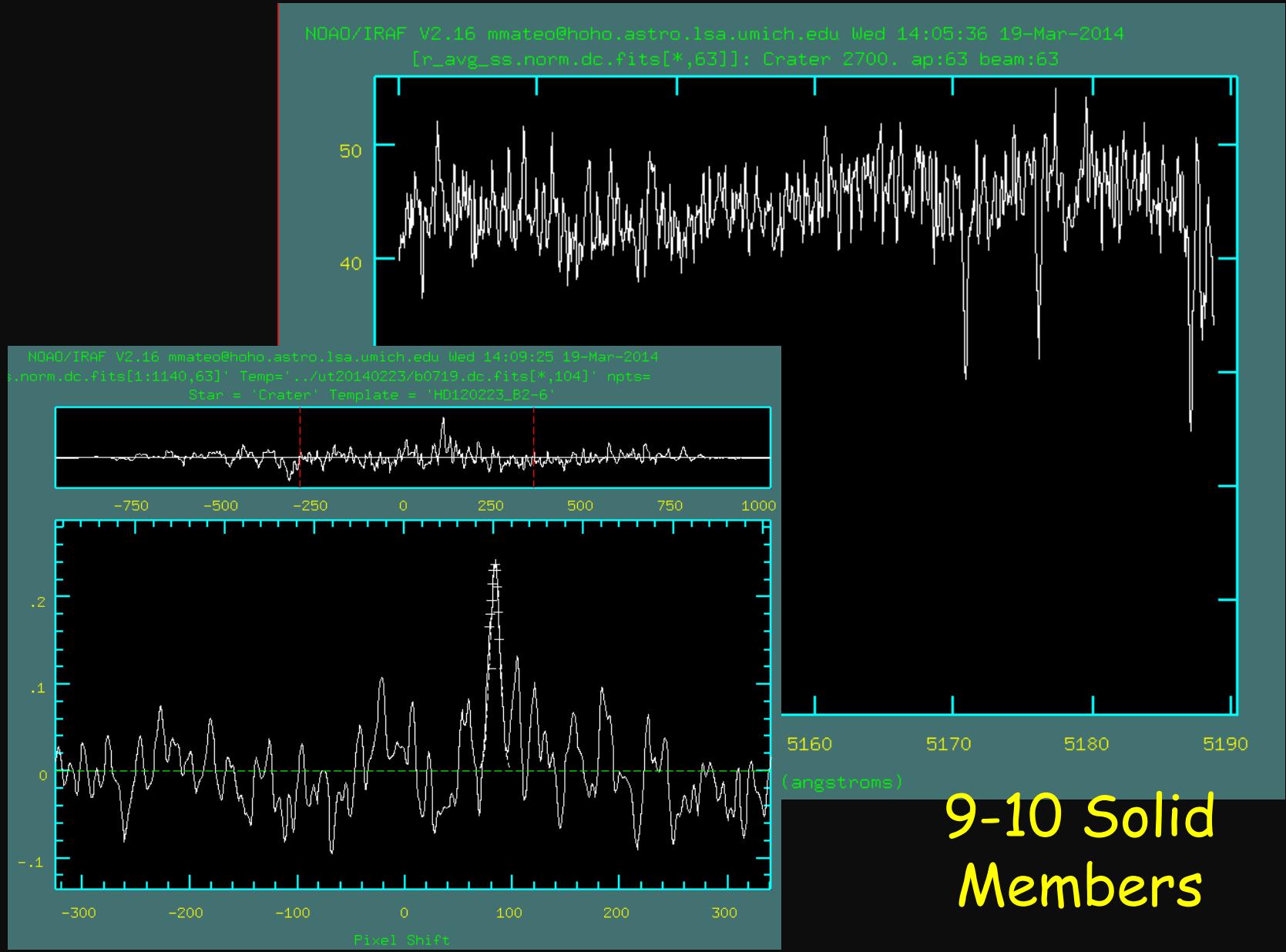


Fornax
Dwarf Galaxy
Dist = 220 kpc
HiRes Spectra
Individual Stars
400 stars/4 hrs





**Abell 267
Galaxy Cluster
 $z = 0.19$
LoRes Spectra
Individual Galaxies
1.5 hrs**



9-10 Solid
Members