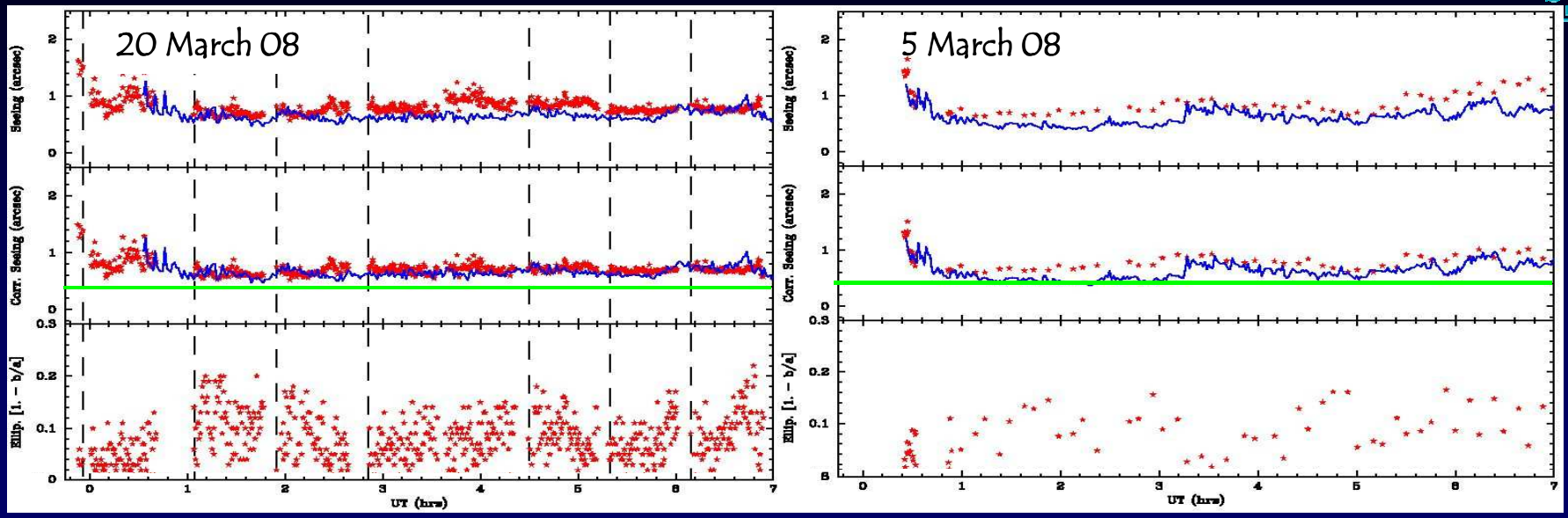
Reducing and Mosaicking SOAR Optical Imager (SOI) Data

S Points (NOAO/CTIO)

Delivered Image Quality



- Optics Tuned
  - After ~1st hour (Typically see rapid change @ start of night)
  - Every ~2 hours during night
  - After Large elevation change
- DIQ matches seeing monitor
  - But significant overhead

- Optics only tuned at start of night
- DIQ much worse than DIMM

- It pays to keep the optics well tuned whenever the seeing is good, however, this entails significant overhead

Observer Tools for DIQ

- Use IRAF and imexam on soaric1:8
  - Only measures 1 star at a time
- Use DIQ script on soaric1
  - Located at /uyw1/simager/diqscripts
  - Only available for images with 2x2 binning
  - Uses combination of SExtractor and gawk scripts

```
================================================================================
For /home2/images/NOAO/2011-01-28/sci.090.fits taken in the V_Bessell filter
and based upon 29 reference star measurements:
================================================================================
Site Seeing (DIMM):              1.21 arcsec
Image Quality:                   1.24 +/- 0.14 arcsec
Image Quality (Airmass Corrected): 1.21 +/- 0.14 arcsec
Average Ellipticity              0.06 +/- 0.05
Average Elongation               1.06 +/- 0.05
AIRMASS:                         1.04
FILTER:                          V_Bessell
EXPTIME:                         300 sec
TIME-OBS:                        08:03:52.9
```

Reducing SOI Data

- Can be done using IRAF and mscred
  - mscred originally written for mosaic
  - Some routines only work assuming 1x1 binning and instrument PA=0 (N – up; E – left)
  - Need an instrument file
- Other useful software
  - SExtractor
  - WCS Tools
  - Astrometry.net tools
  - PyRAF
  - Other miscellaneous scripts (ds9mark.pl, queryCDSpipe.py)

Reducing SOI Data (Cont)

- Problems with the FITS headers
  - Keyword values for BIASSEC, TRIMSEC, DATASEC are incorrect
    - Makes it hard to perform basic reductions (i.e, bias-subtract, zero-subtract, flat-field, etc)
  - Keyword values for CRPIXn are incorrect
    - Makes it hard to obtain astrometric solution
  - Keyword values for CD matrices incorrect
    - Makes it impossible to obtain astrometric solution
  - Others?
    - Users should send me comments/suggestions

Reducing SOI Data (Cont)

- FITS header keyword remediation
  - Correct On-the-Fly as you reduce the data
    - Involves more time/work on the part of the observer
    - Not ideal for large data sets
    - Short-term solution
  - Correct in the instrument data handling system
    - Better for everybody
    - Need to obtain resources to implement the changes
    - Long-term solution

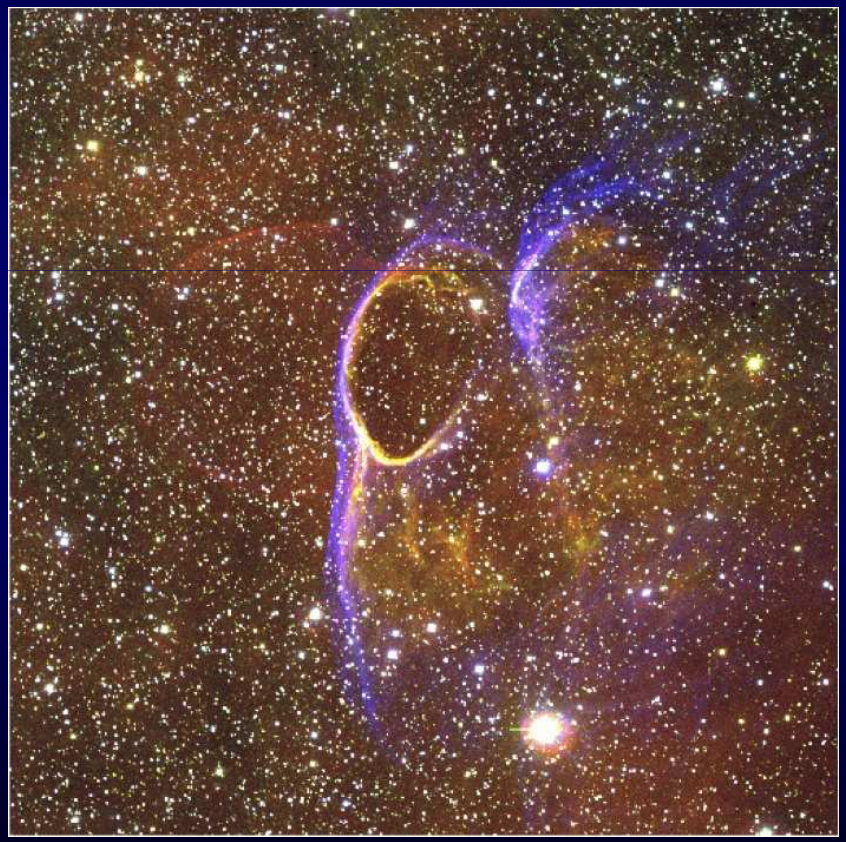
Reducing SOI Data (Cont)

- General procedure
  - Remediate FITS keyword values
  - Overscan-correction
  - Zero combine
  - Zero-subtraction
  - Flat-field combine
  - Flat-field correction
  - Split data
  - Combine individual amps for each CCD
  - Perform basic astrometric correction
  - Perform real astrometric correction
  - Mosaic data

The Project

- **Vela Knot C**
  - 6 knots of X-ray emission detected beyond Vela's shell
  - Emission arises from ejecta from the SN event
  - Observed in Hα, [SII], [O III], "red" and "green" continuum
  - Discovered Balmer-dominated filament beyond leading edge of radiative shock front, tracing pre-existing bubble in ISM
  - Follow-up Hα imaging to check for proper motion of filaments with Mosaic II (2006) and SOI (2011)

CTIO UM Curtis Schmidt



The Data

- SOI
  - 6 pointings to cover Balmer-dominated filament
  - Use Winkler Hα (6572Å/25Å) and "red" continuum (6852Å/95Å) filters
  - 3x300s (Hα) per pointing
  - 3x200s (red) per pointing
  - 10" offsets EW per pointing to cover chip-gap
  - 2x2 binning (0.154"/pixel)
  - Instrument rotator PA=180°

The Reductions

- **Remediate FITS keyword values for TRIMSEC, DATASEC, and BIASSEC with mscred.ccdhedit**

```
csh> gethead -x TRIMSEC DATASEC BIASSEC *fits
vela.182.fits       [1] [26:537,1:2048] [26:537,1:2048] [538:568,1:2048]
vela.182.fits       [2] [32:543,1:2048] [32:543,1:2048] [1:31,1:2048]
vela.182.fits       [3] [26:537,1:2048] [26:537,1:2048] [538:568,1:2048]
vela.182.fits       [4] [32:543,1:2048] [32:543,1:2048] [1:31,1:2048]
```

- **Should be**

```
csh> gethead –x TRIMSEC DATASEC BIASSEC *fits
vela.182.fits       [1] [29:540,1:2048] [29:540,1:2048] [541:568,1:2048]
vela.182.fits       [2] [29:540,1:2048] [29:540,1:2048] [1:28,1:2048]
vela.182.fits       [3] [29:540,1:2048] [29:540,1:2048] [541:568,1:2048]
vela.182.fits       [4] [29:540,1:2048] [29:540,1:2048] [1:28,1:2048]
```

The Reductions (Cont)

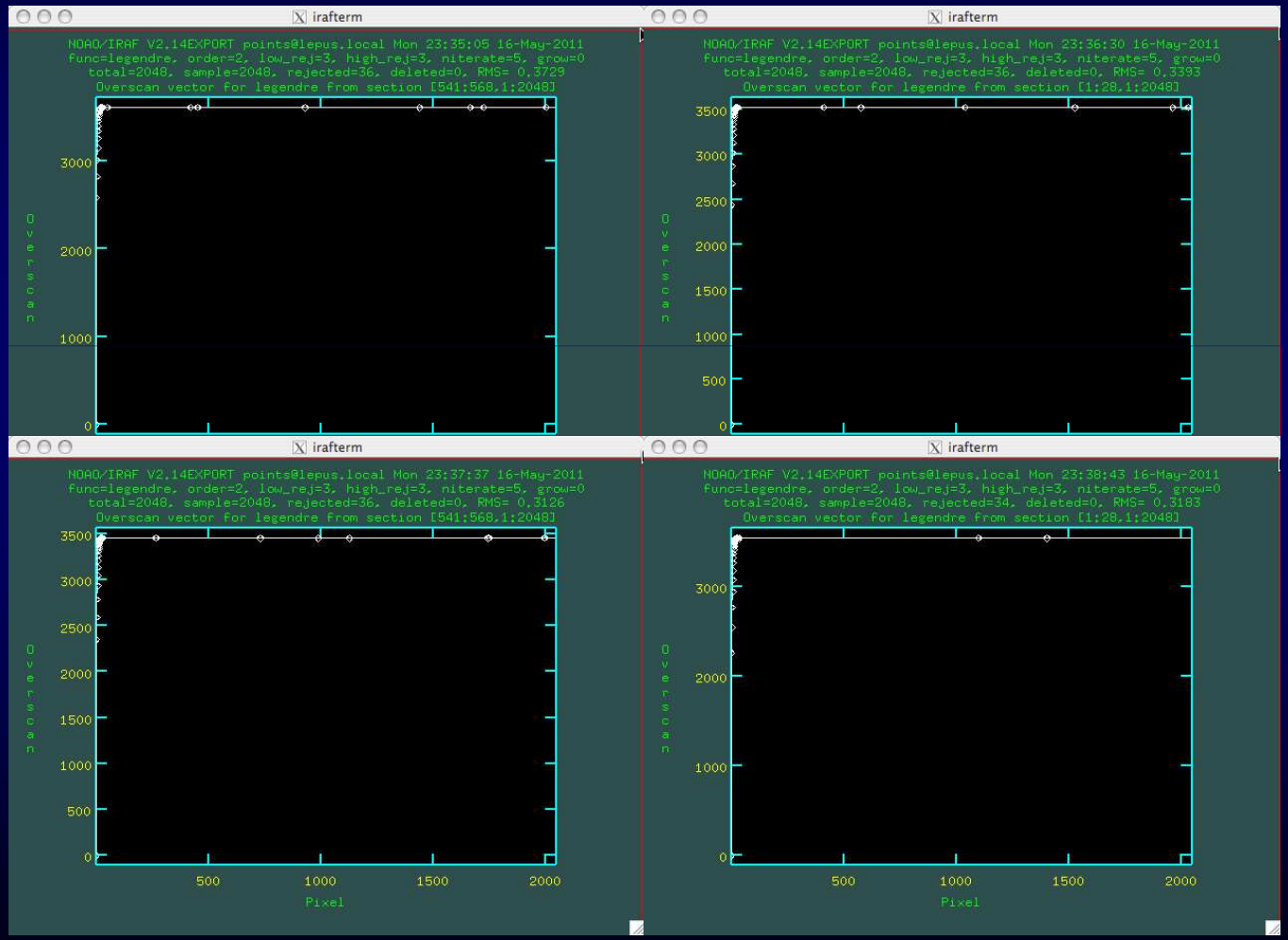
- **Create filter subsets**

```
csh> gethead FILPOS *fits
    ...
    dflat2x2_ha.040.fits  2 1
    ...
    dflat2x2_red.026.fits 3 1
    ...
mscred> hsel *.fits[1] $I 'filpos == "2 1"' > listha
mscred> hsel *.fits[1] $I 'filpos == "3 1"' > listred
mscred> soiupfilter @listha2 filter_=yes filter=wha
mscred> soiupfilter @listred2 filter_=yes filter=wred
mscred> ccdlist *fits[1]
    vela.182.fits[1][568,2048][ushort][object][1][wred]:Vela KnotC
    vela.183.fits[1][568,2048][ushort][object][1][wred]:Vela KnotC
    vela.184.fits[1][568,2048][ushort][object][1][wred]:Vela KnotC
    vela.185.fits[1][568,2048][ushort][object][1][wha]:Vela KnotC H-alpha
    vela.186.fits[1][568,2048][ushort][object][1][wha]:Vela KnotC H-alpha
    vela.187.fits[1][568,2048][ushort][object][1][wha]:Vela KnotC H-alpha
```

The Reductions (Cont)

- **Overscan-correction and trimming the data**

  mscred> ccdproc *fits process=yes oversca=yes trim=yes



The Reductions (Cont)

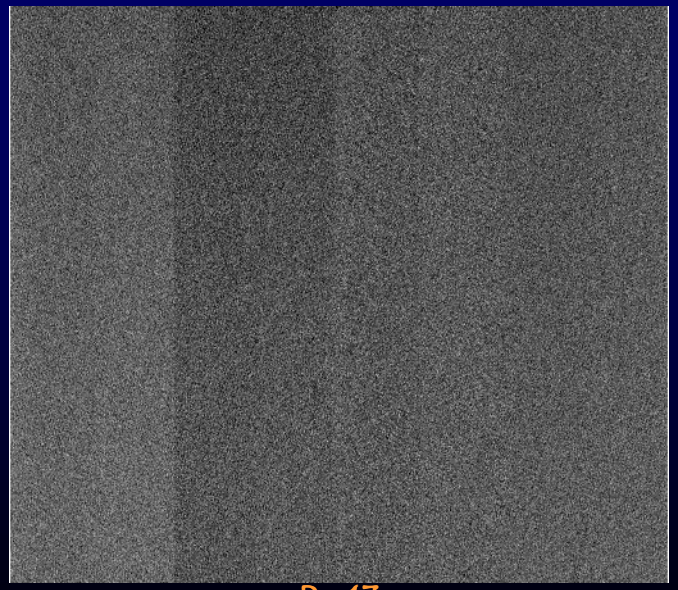
- **Check overscan and trim corrections**

  mscred> ccdlist *fits[1]

  vela.182.fits[1][512,2048][real][object][1][wred][OT]:Vela KnotC
  vela.183.fits[1][512,2048][real][object][1][wred][OT]:Vela KnotC
  vela.184.fits[1][512,2048][real][object][1][wred][OT]:Vela KnotC
  vela.185.fits[1][512,2048][real][object][1][wha][OT]:Vela KnotC H-alpha
  vela.186.fits[1][512,2048][real][object][1][wha][OT]:Vela KnotC H-alpha
  vela.187.fits[1][512,2048][real][object][1][wha][OT]:Vela KnotC H-alpha

- **Zero-combine**

  mscred> zerocombine zero*fits output=Zero.20110413.fits



The Reductions (Cont)

- **Zero-subtract**

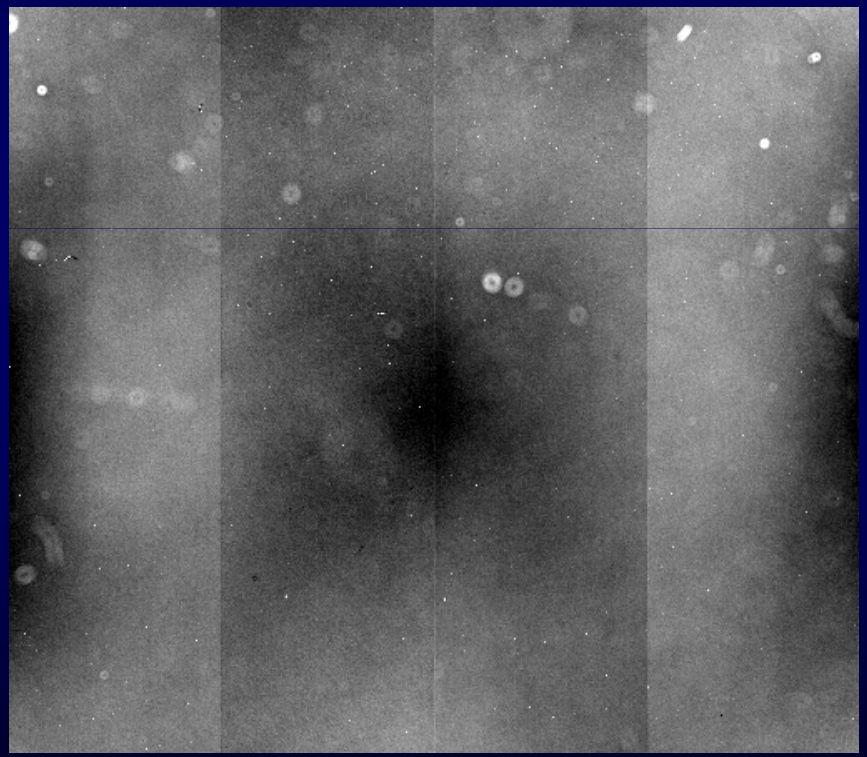
```
mscred> ccdproc *fits zerocor=yes zero=Zero.20110413.fits
mscred> ccdlist *fits[1]
    vela.182.fits[1][512,2048][real][object][1][wred][OTZ]:Vela KnotC
    vela.183.fits[1][512,2048][real][object][1][wred][OTZ]:Vela KnotC
    vela.184.fits[1][512,2048][real][object][1][wred][OTZ]:Vela KnotC
    vela.185.fits[1][512,2048][real][object][1][wha][OTZ]:Vela KnotC H-alpha
    vela.186.fits[1][512,2048][real][object][1][wha][OTZ]:Vela KnotC H-alpha
    vela.187.fits[1][512,2048][real][object][1][wha][OTZ]:Vela KnotC H-alpha
```

- **Flat combine**

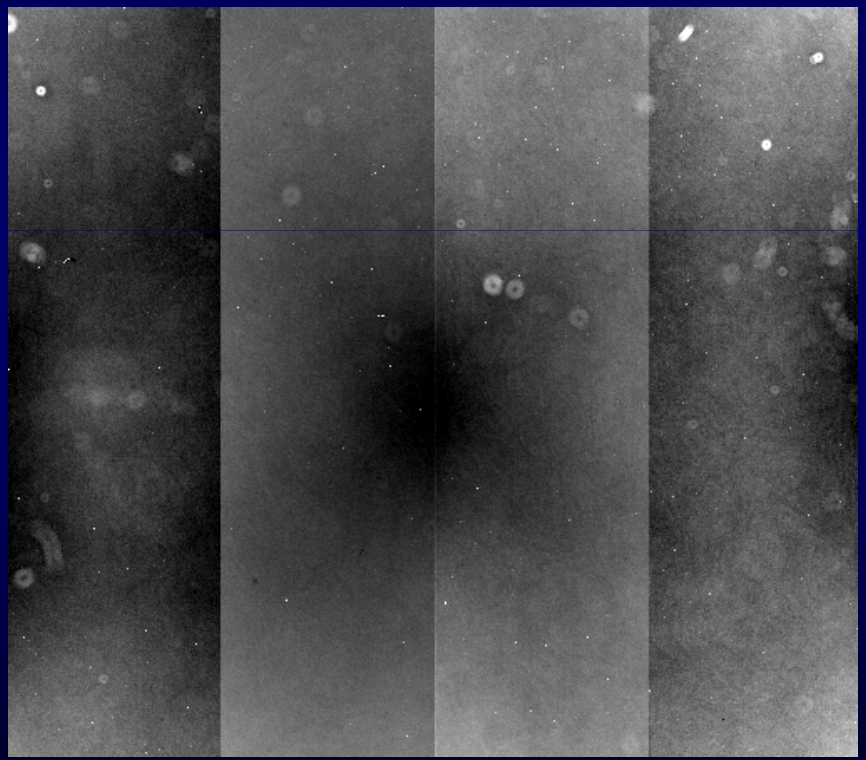
```
mscred> flatcomb sflat*fits output=Sflat_
     Images     Exp    Mode  Scale
    sflat2x2_ha.172.fits[1]   15.0  15392.  1.000
    sflat2x2_ha.173.fits[1]   20.0  18070.  0.852
    sflat2x2_ha.174.fits[1]   25.0  19450.  0.791
    sflat2x2_ha.175.fits[1]   25.0  16475.  0.934
```

The Reductions (Cont)

Hα



Red



The Reductions (Cont)

- **Flat-field correct**

```
mscred> ccdproc *fits sflatco=yes sflat=Sflat
mscred> ccdlist *fits[1]
    vela.182.fits[1][512,2048][real][object][1][wred][OTZS]:Vela KnotC
    vela.183.fits[1][512,2048][real][object][1][wred][OTZS]:Vela KnotC
    vela.184.fits[1][512,2048][real][object][1][wred][OTZS]:Vela KnotC
    vela.185.fits[1][512,2048][real][object][1][wha][OTZS]:Vela KnotC H-alpha
    vela.186.fits[1][512,2048][real][object][1][wha][OTZS]:Vela KnotC H-alpha
    vela.187.fits[1][512,2048][real][object][1][wha][OTZS]:Vela KnotC H-alpha
```

- **Split data into individual amps**

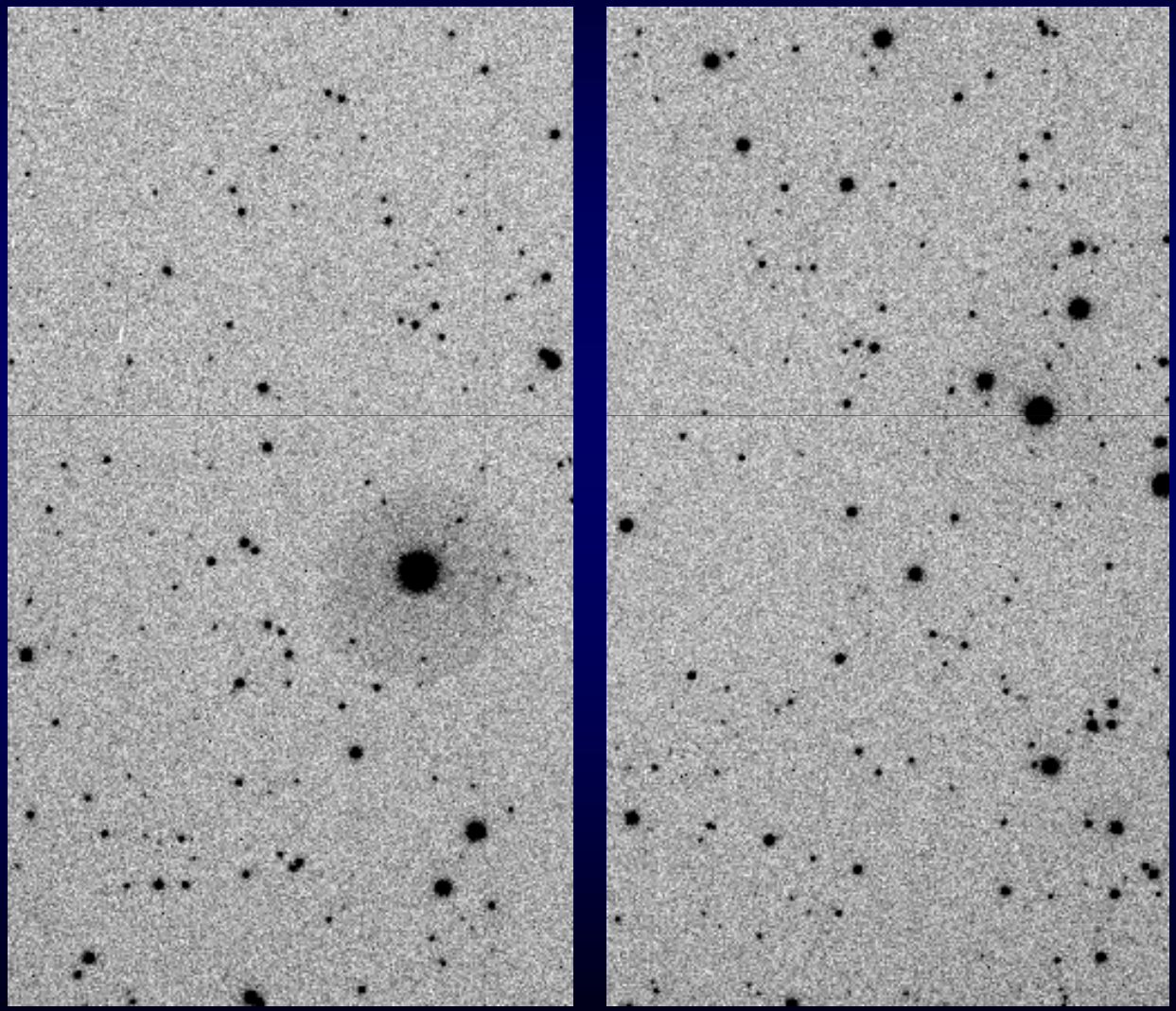
```
mscred> mscsplit vela*fits
mscred> ls vela.182*
    vela.182.fits    vela.182_1.fits  vela.182_3.fits
    vela.182_0.fits  vela.182_2.fits  vela.182_4.fits
```

- **Join amps 1 & 2 and amps 3 & 4**

```
imutil>  imjoin vela.182_1.fits,vela.182_2.fits out=vela.182_12.fits
    join_dim=1
Join: vela.182_1.fits size: 512 X 2048  ->  vela.182_12.fits[1:512,1:2048]
Join: vela.182_2.fits size: 512 X 2048  ->  vela.182_12.fits[513:1024,1:2048]
```

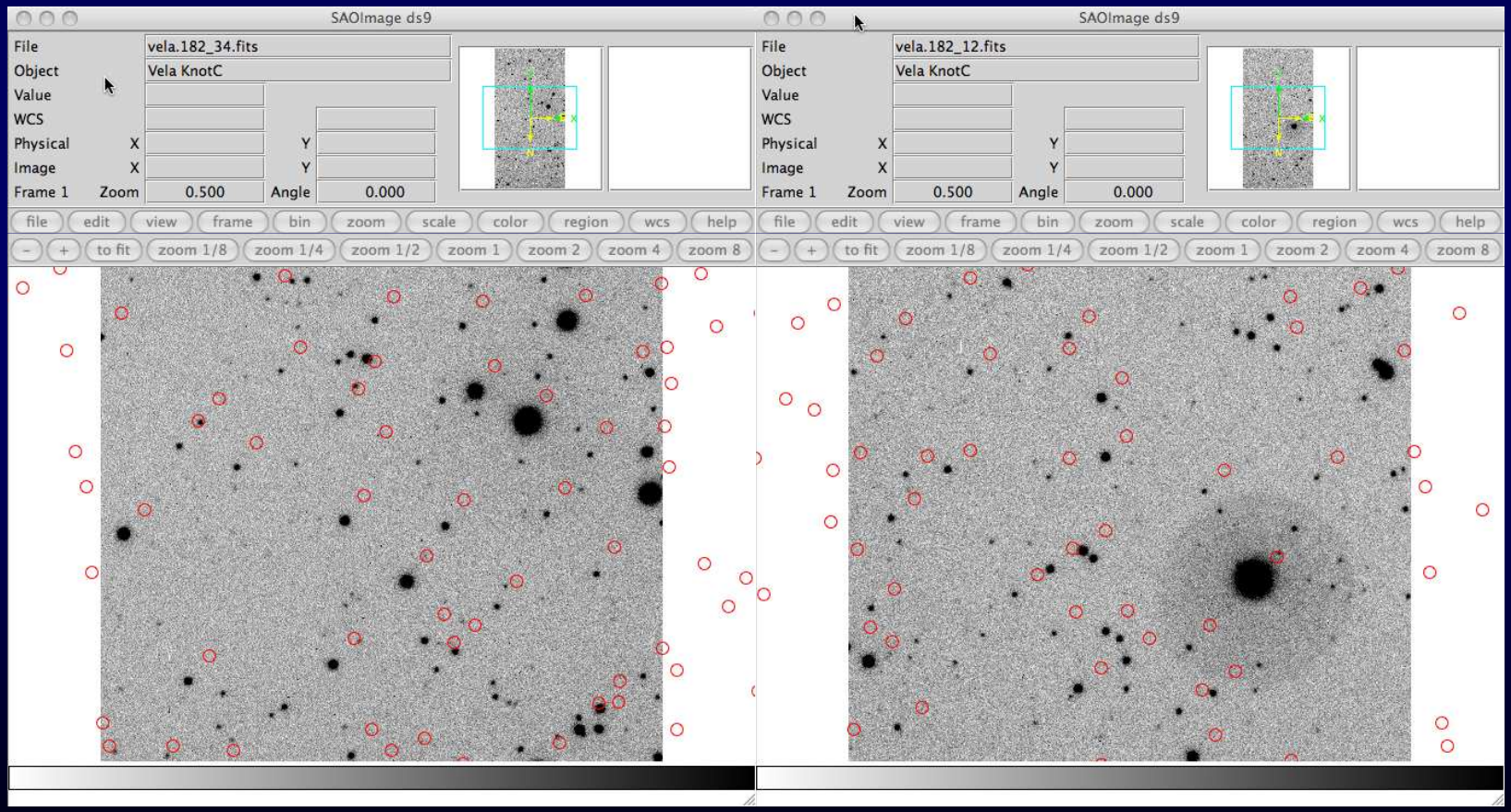
The Reductions (Cont)

- **Check the joined images**



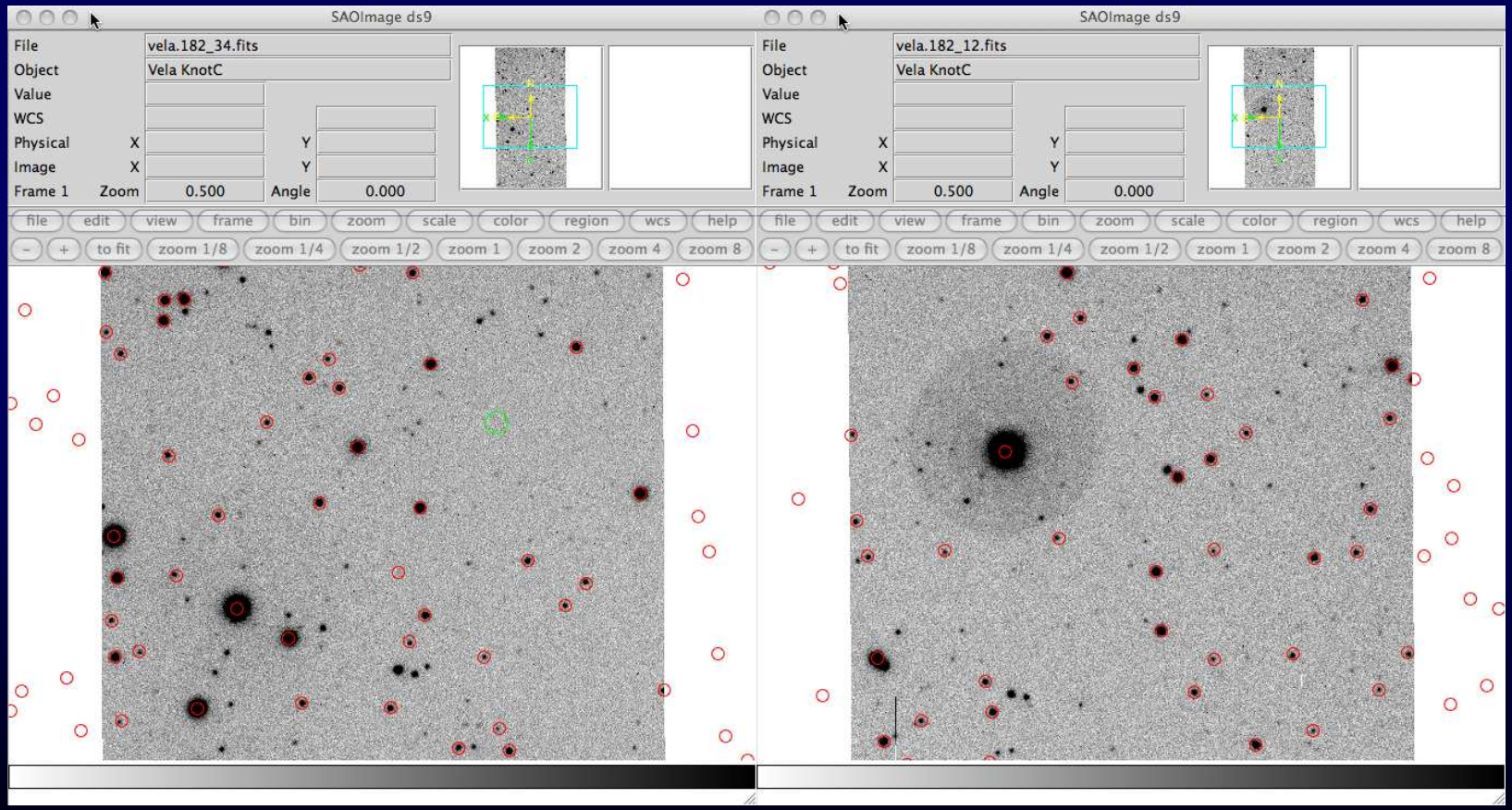
The Reductions (Cont)

- Fix FITS Header keywords for astrometry
  - Set CRPIXn to center of chip gap (102 unbinned pixels)
  - Invert CD2_2
- Check new astrometry



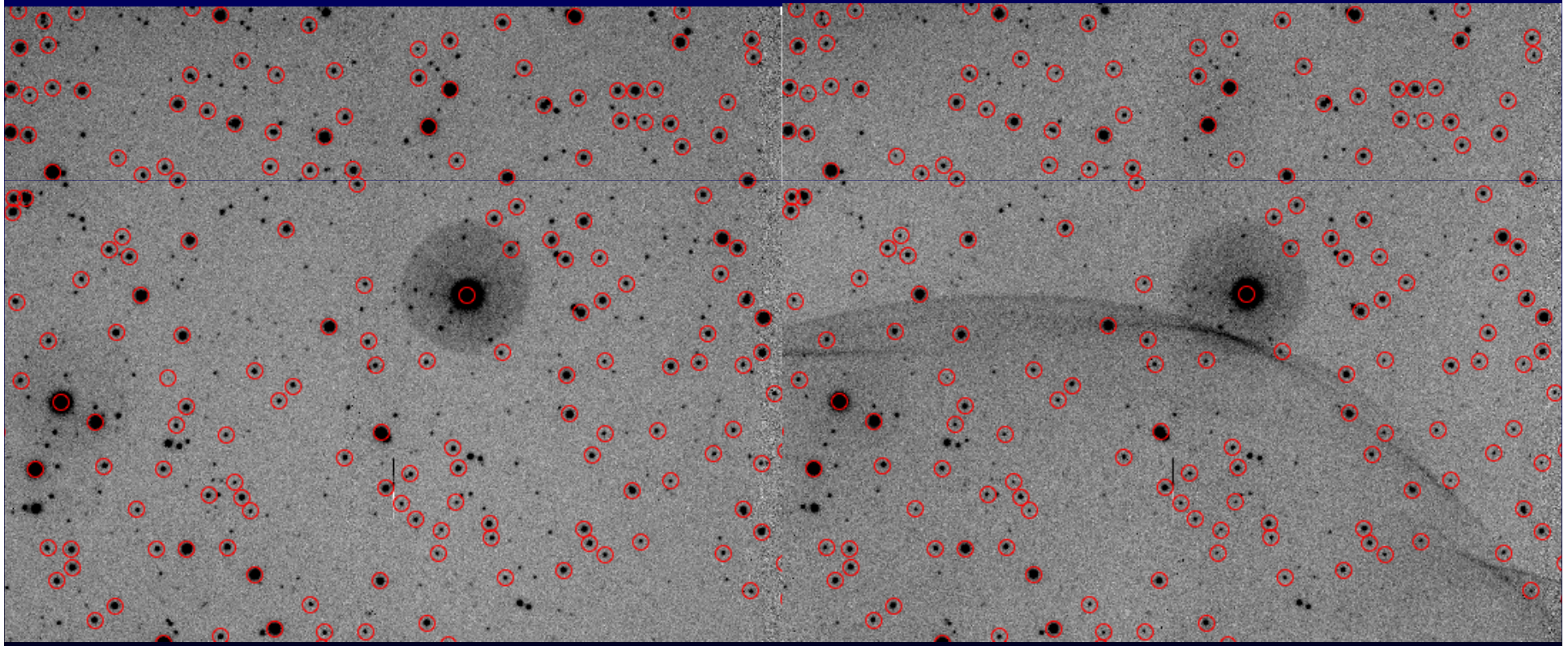
The Reductions (Cont)

- Astrometry is better, but not perfect
- Use IRAF utilities, ccfind, ccmap, and ccsetwcs to improve astrometric error to ~ ½ pix



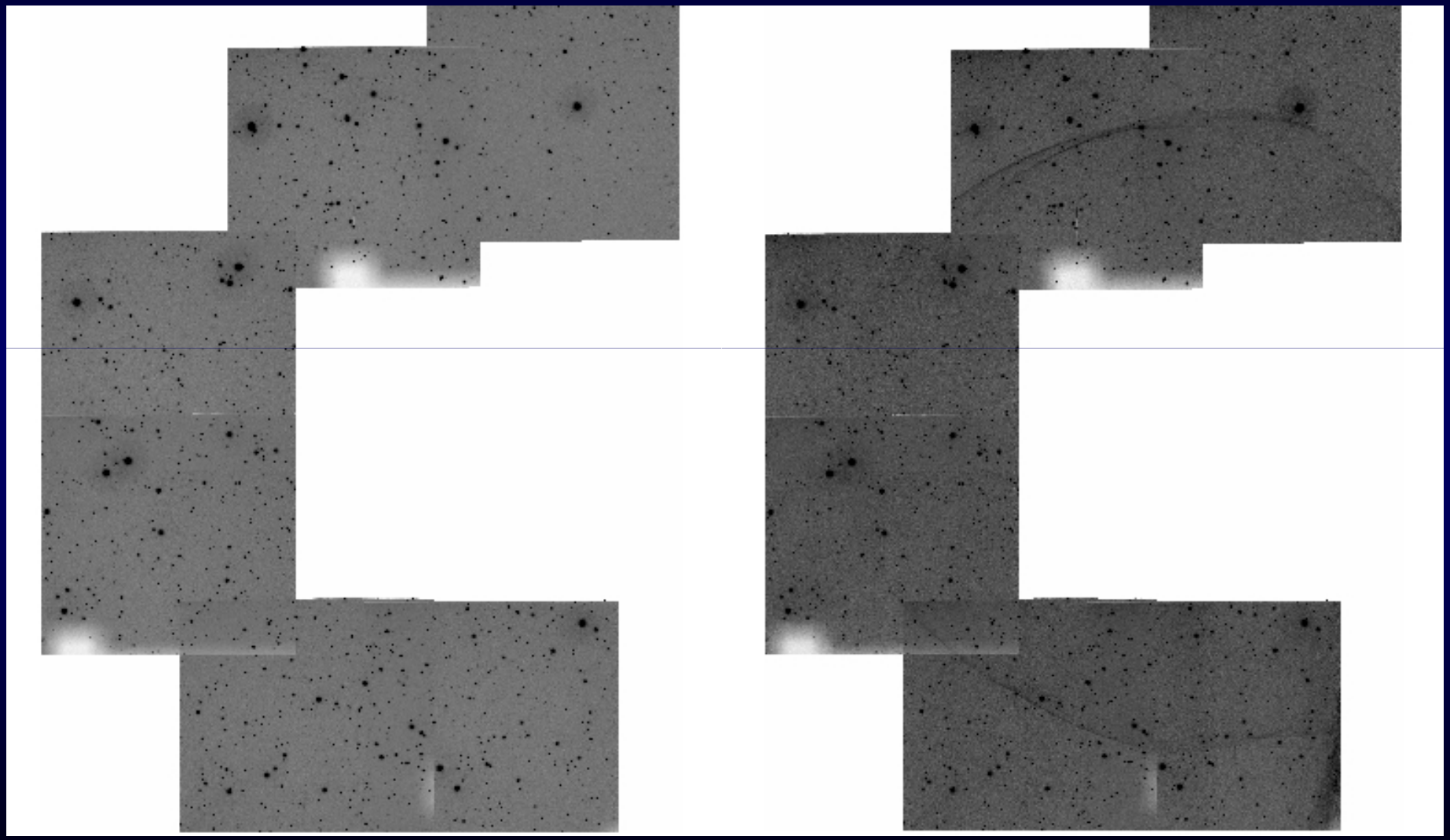
The Reductions (Cont)

- Mosaic the data for each field
- Use IRAF routines mkpattern and ccsetwcs to put coordinates on reference image for each pointing
- Use IRAF imcombine on the results



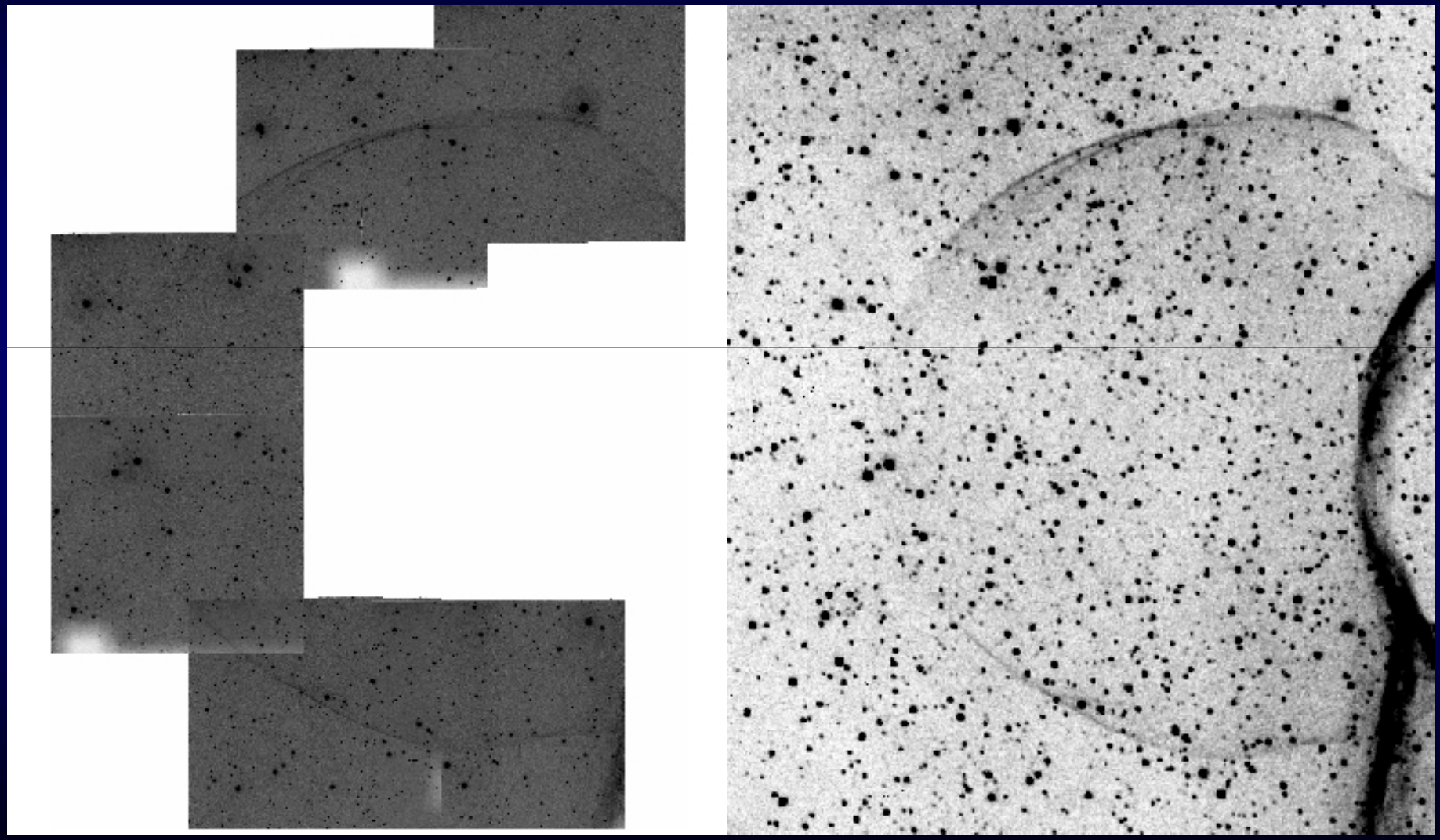
Mosaic the Fields

- **Mosaic all fields into a wide-field map**



Results

- **Is the Balmer-dominated filament moving?**



Conclusions

- Easy to track DIQ over the night with SOI
- Reducing SOI data is relatively easy
- Problems exist with header keyword values
  - Current solution: observers fix the headers
  - Long-Term Solution: SOAR & CTIO staff fix the problem at the source
- All reduction steps are easily scripted/pipe-lined
- More complete notes will be on SOI webpage
- Any comments, suggestions, or problems?
  - Email: *spoints@ctio.noao.edu*