Michigan Infrared Combiner: MIRC Update

John Monnier

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Outline

- What is MIRC?
- Year 1 (2006) Summary
- Current Status
  - Sensitivity, Calibration, Modes
- Intro to: How to observe with MIRC
  - Differences from CLASSIC
- Pipeline
  - Creates a beautiful full-featured OI-FITS file..
- Imaging and Imaging Campaigns
- Current observing philosophy…

MIRC: Near-IR Imaging Combiner

Guiding Principles:

1) Maximum Calibration Precision for Closure Phases
2) Imaging

- Infrared Sensitivity (H/K, 1.45-2.4 microns)
- Image Plane Combination
  - Configured for 4 telescopes:6 baselines, 4 triangles
- Spectral Dispersion: R~44, 150 or 400
- Spatial Filtering with SM Fibers
  - Photometric monitoring possible in future upgrade
- Integrated with CHARA-Michigan Phasetracker
  - See next talk on CHAMP by Dave Berger

Op

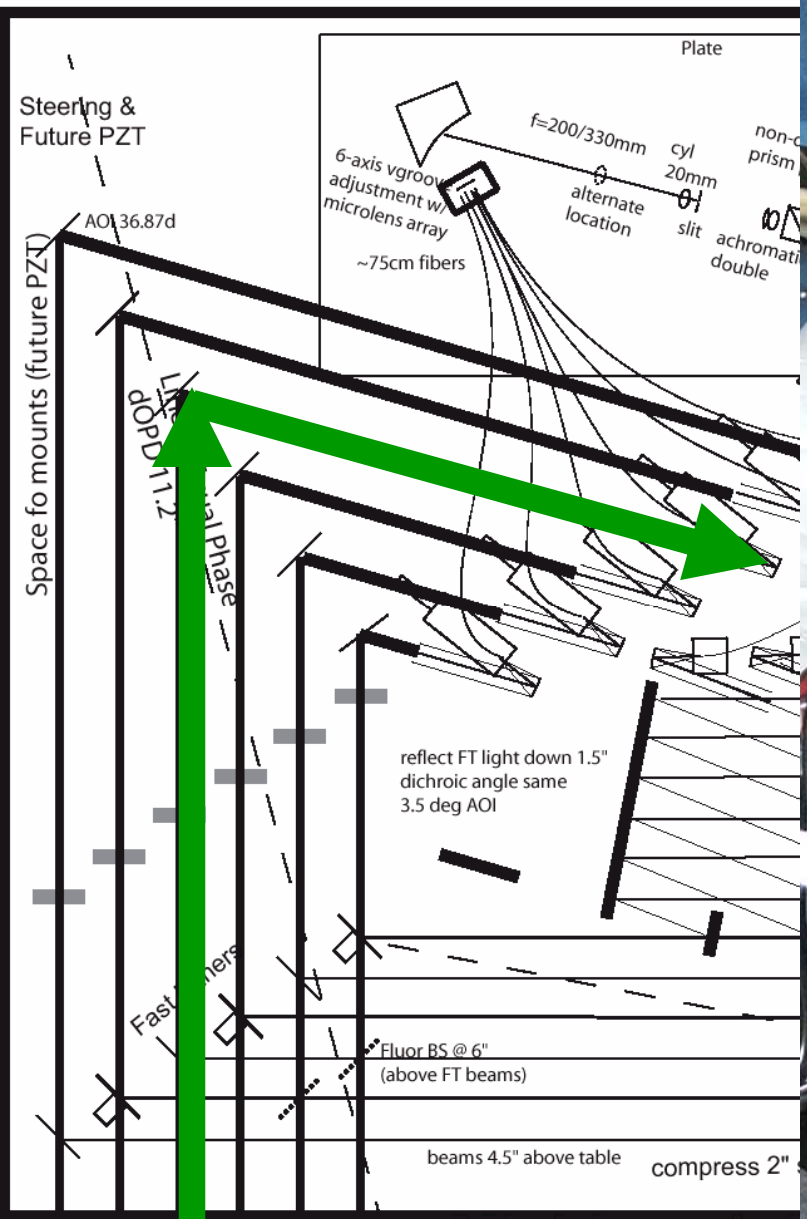
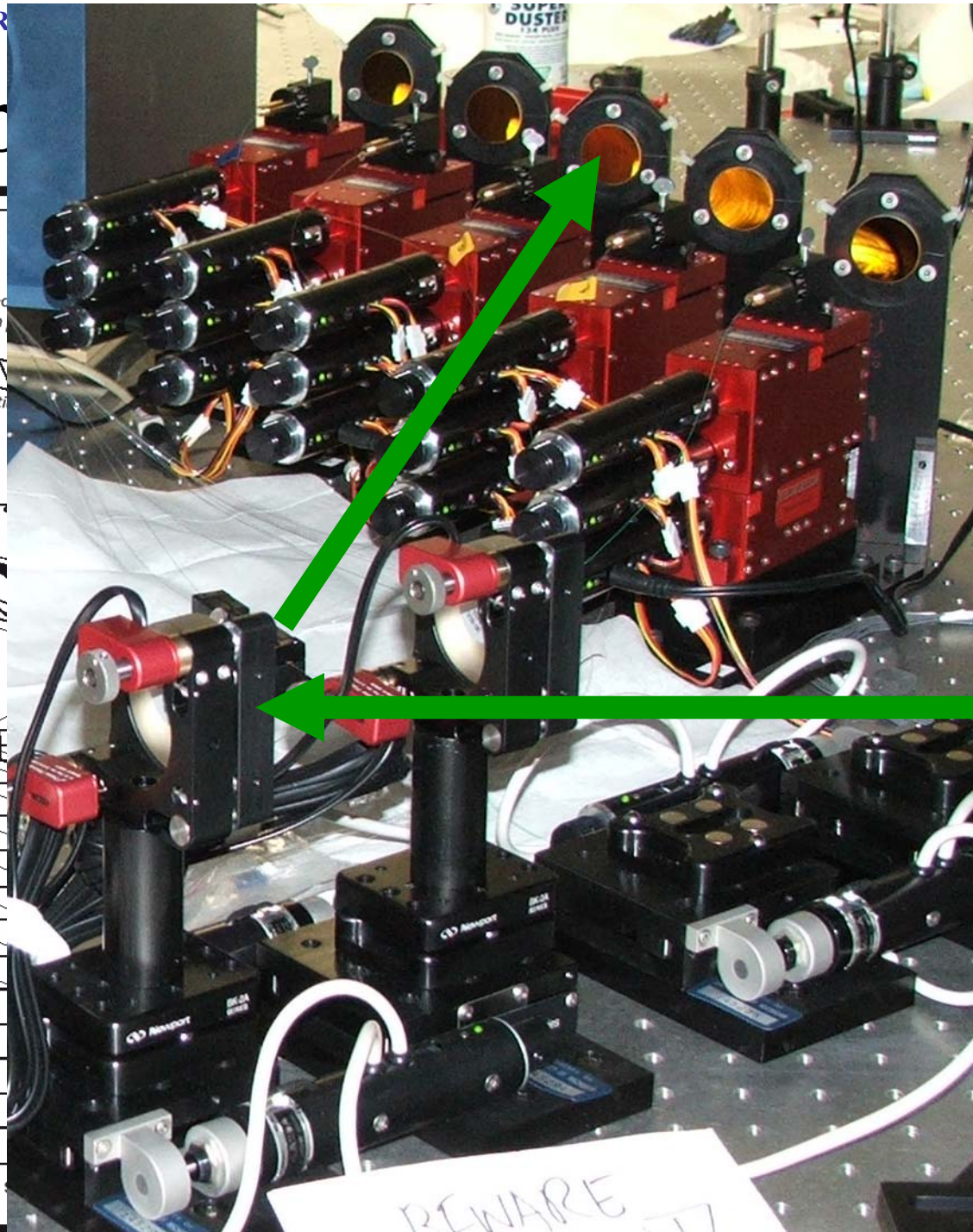
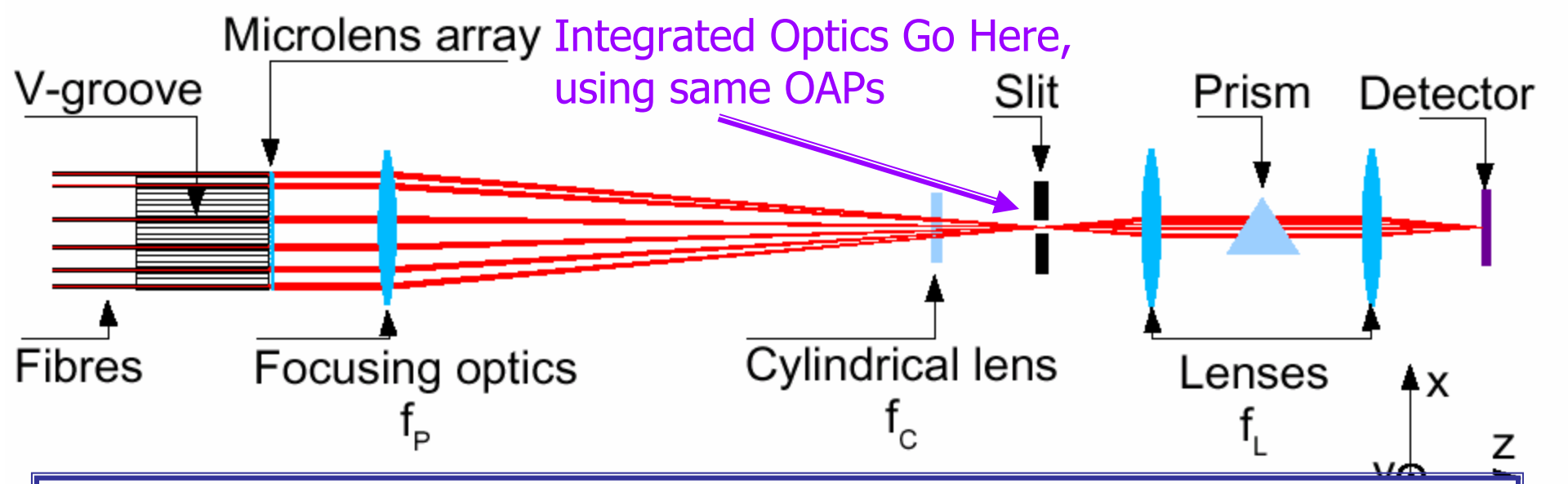
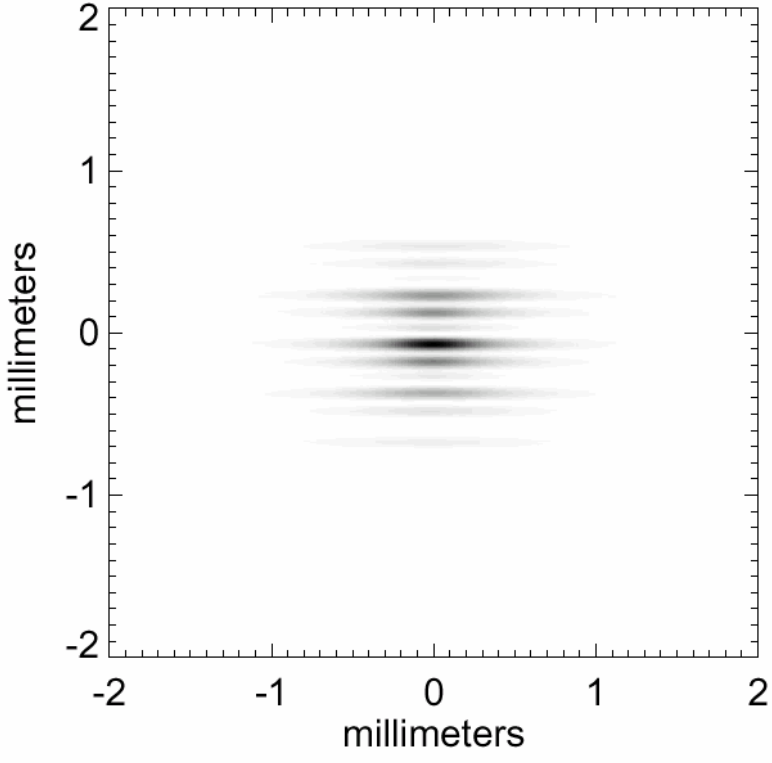
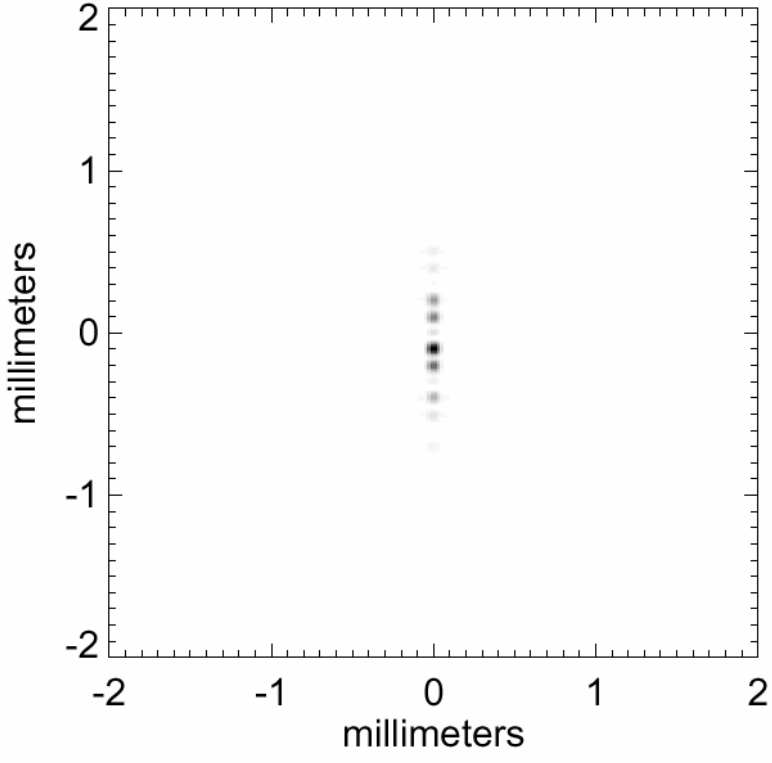


Plate
Steering &
Future PZT
f=200/330mm
cyl
20mm
alternate
location
slit
6-axis vgroov
adjustment w/
microlens array
~75cm fibers
AOI 36.87d
Space fo mounts (future PZT)
dOPD 11.2
reflect FT light down 1.5"
dichroic angle same
3.5 deg AOI
Fluor BS @ 6"
(above FT beams)
beams 4.5" above table
compress 2"

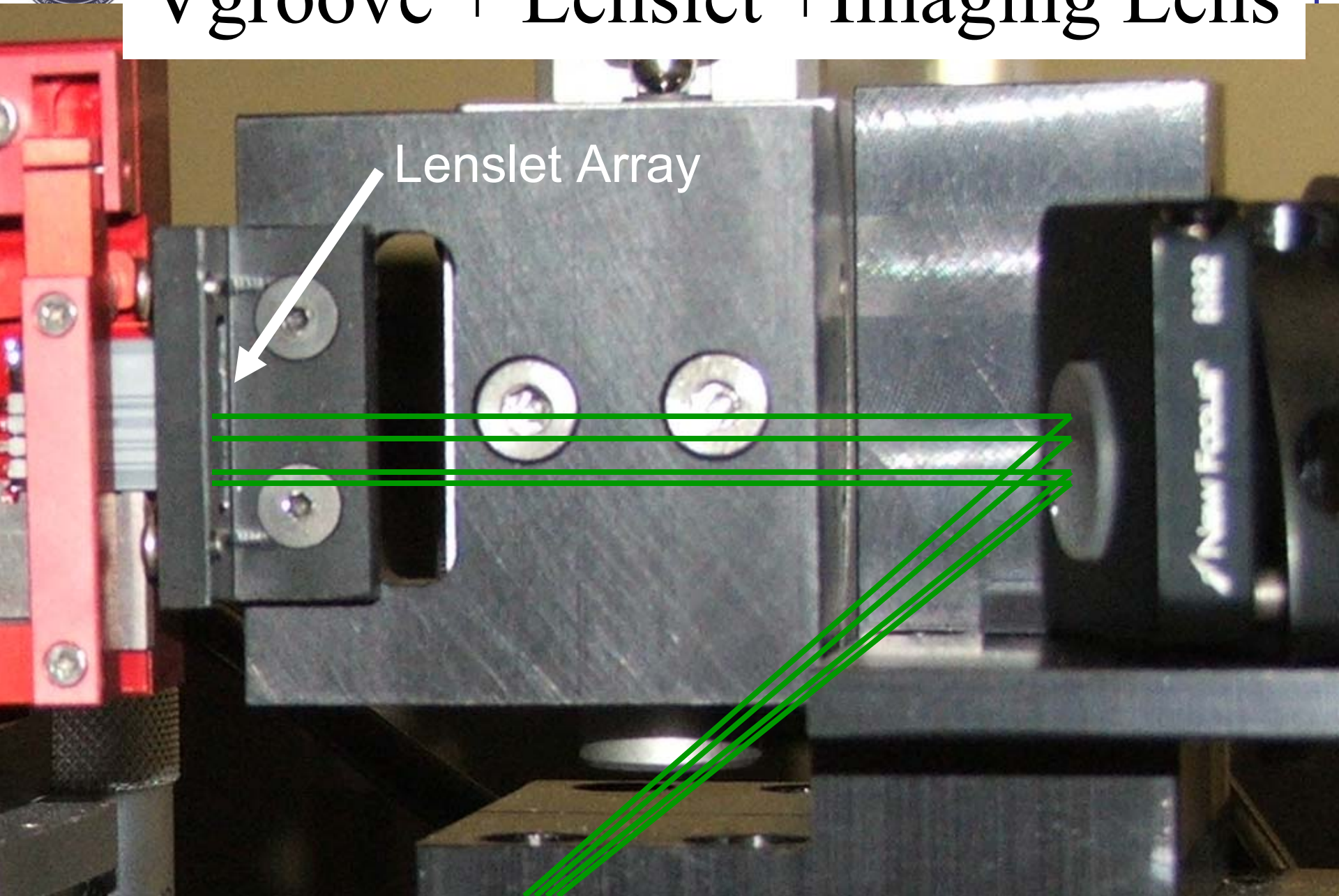



Microlens array
Integrated Optics Go Here,
using same OAPs
V-groove
Slit
Prism
Detector
Fibres
Focusing optics
f_P
Cylindrical lens
f_C
Lenses
f_L
x
z

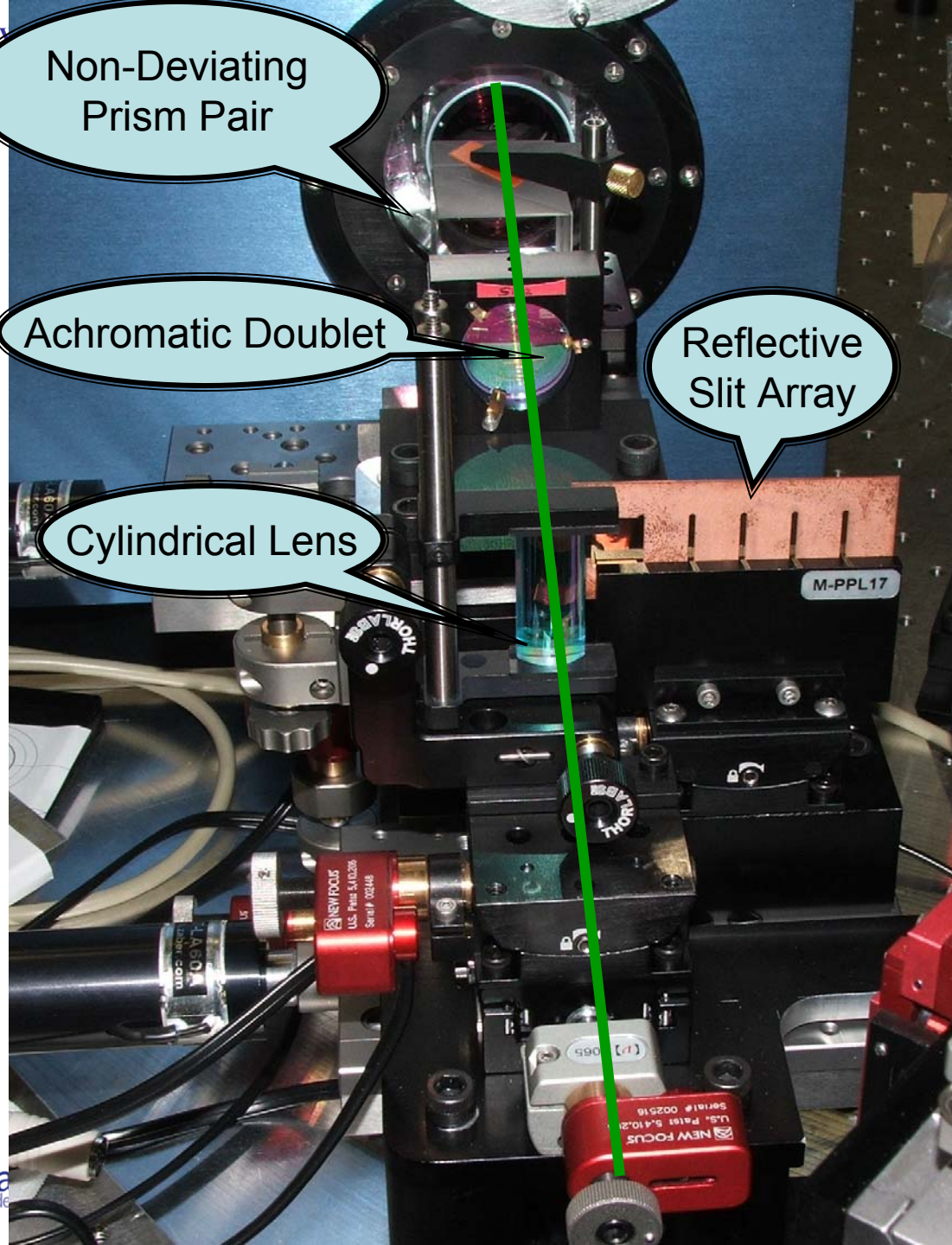

No Cylindrical Lens
millimeters
millimeters
2
1
0
-1
-2


With Cylindrical Lens
millimeters
millimeters
2
1
0
-1
-2

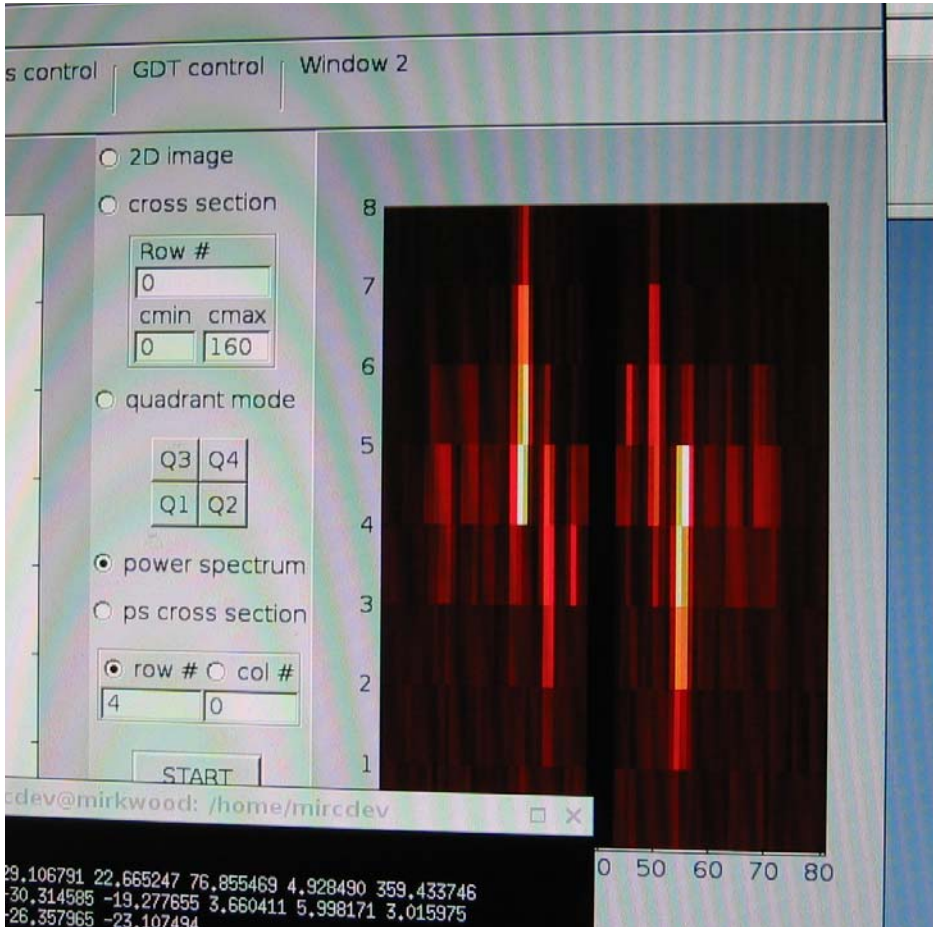
Vgroove + Lenslet +Imaging Lens



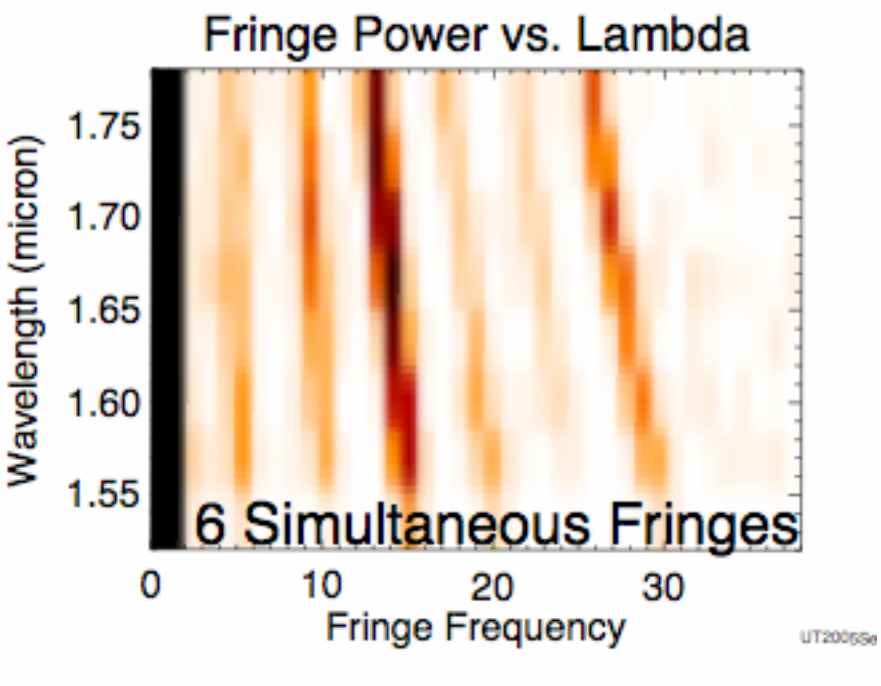
View along beam into Camera

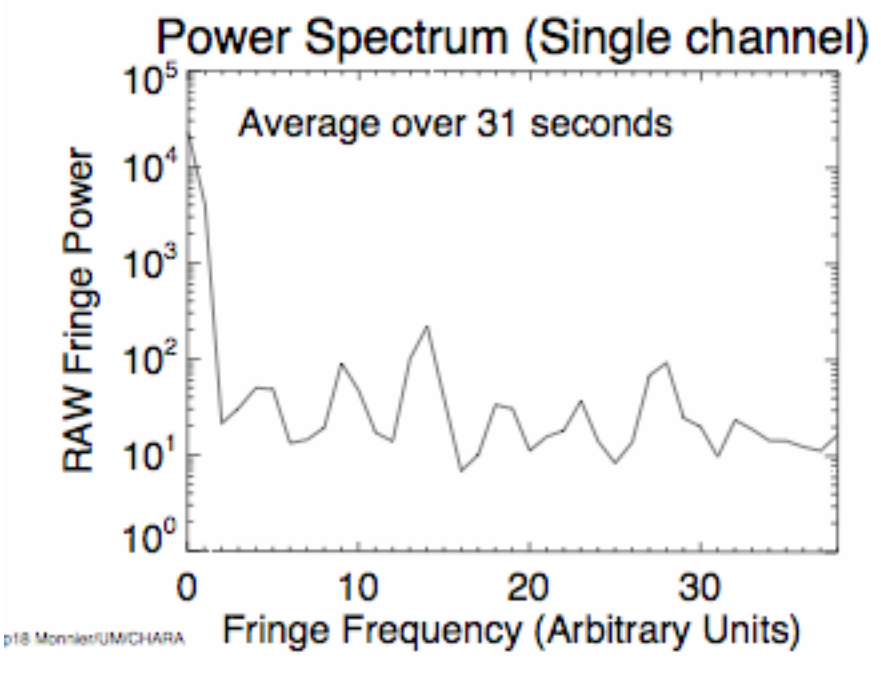


4-Telescope Operation: 2005 Sep 18



6 Simultaneous Fringes on Binary Iota Peg (H=2.7)





UT2005Se p18 Monnier/UM/CHARA

MIRC: Year 1 (2006) Summary

- Observing
  - 19 nights with data spread over 3 runs
  - MIRC survived vacuum pump failure and a very special backup regiment
- Personnel
  - Nathalie Thureau went back to COAST group
  - Ettore Pedretti began fellowship @ St. Andrews
  - Ming Zhao (grad student@UM) received 2006 Michelson Graduate Fellowship

Known Problems (and solutions)

- Difficult to find fringes if delay > 1 mm
  - Use NIRO at beginning of run (or better baseline model or get fringe tracker going)
- Visibility amplitude calibration
  - Large changes were observed in mean fiber coupling between shutter sets
  - Better estimate using fiber profiles
- Flakey serial cable with fiber mounts…
  …annoying

MIRC Improvements 2006

- Installed Choppers on all 4 beams
  - Generally much better calibration of amplitude information.. But not perfect. varies 5-15% inV2
  - MIRC upgrade to photometric channels is slowly proceeding as low priority
- Files now have Rich Headers

HEADERS

- SIMPLE = T / file does conform to FITS standard
- BITPIX = 16 / number of bits per data pixel
- NAXIS = 3 / number of data axes
- NAXIS1 = 1280 / length of data axis 1
- NAXIS2 = 16 / length of data axis 2
- NAXIS3 = 1000 / length of data axis 3
- EXTEND = T / FITS dataset may contain extensions
- COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy
- COMMENT and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
- BZERO = 32768 / offset data range to that of unsigned short
- BSCALE = 1 / default scaling factor

- DATE = '2006-10-16T04:06:49' / File creation date (YYYY-MM-DDThh:mm:ss UTC)
- TELESCOP= 'CHARA array 330m max baseline, 6dishes' / Telescope
- INSTURME= 'MIRC spectro/combiner' / The data acquisition instrument
- ORIGIN = 'Mount Wilson Institute' / Origin of the Observation
- SITELAT = '34.13.54' / Latitude (Geodetic, VLBI, to be verified)
- SITELONG= '118.03.33' / Longitude (Geodetic, VLBI, to be verified)
- SITEELEV= '5680.00 ' / Altitude above MSL, to be verified
- HISTORY = 'Multi-Dish FITS data' / File modification history
- OBSERVER= 'Slimfringe ' / Observer name
- DATE-OBS= '10/16/2006' / UT date (YYYY-MM-DD)
- UTC-OBS = '03:13:20.000' / Universal Time hh:mm:ss.ddd
- LST-OBS = '20:59:07.631' / Local Sidereal Time hh:mm:ss.ddd
- OBJECT = 'SHELIAK ' / Target name
- IRC = 'IRC+30343' / Target IRC no..
- HR = 'HR_7106 ' / Target HR no..
- HD = 'HD_174639' / Target HD no..
- SAO = 'SAO_67452' / Target sao no..
- RA = '18:50:04.795' / Right ascension hh:mm:ss.ddd
- DEC = '28: 3: 11.92' / Declination dd:mm:ss.dd
- PM_RA = 6.38518895238101E-09 / RA proper motion (rad/year)
- PM_DEC = -2.16226[illegible]4853E-08 / Dec proper motion (rad/yr)
- PARALLAX= [illegible] / Parallax (arcseconds)

HEADERS

- PARALLAX= 0.0037 / Parallax (arcseconds)
- RADVEL = -19.2 / Radial velocity (km/s)
- VMAG = 3.52 / V magnitude
- KMAG = 0. / K magnitude
- SPECTYPE= 'B7Ve+...' / Spectral type
- WAVELEN = 1.65 / Central wavelength
- BANDWID = 0.3 / Bandwidth of spectrum
- AZ = '27: 2: 39.75' / Azimuth dd:mm:ss.dd
- EL = '63:20:21.68' / Elevation dd:mm:ss.dd
- HA = '02:08:48.289' / Hour Angle hh:mm:ss.ddd
- U_S1-S2 = 14.6458157578675 / u coord. (m)
- V_S1-S2 = -30.3498772583739 / v coord. (m)
- U_S1-E1 = -11.7548894085598 / u coord. (m)
- V_S1-E1 = -327.56326588222 / v coord. (m)
- U_S1-E2 = 22.501492562389 / u coord. (m)
- V_S1-E2 = -277.263689483701 / v coord. (m)
- U_S1-W1 = 217.748767979347 / u coord. (m)
- V_S1-W1 = -153.79583374495 / v coord. (m)
- U_S1-W2 = 118.010440211533 / u coord. (m)
- V_S1-W2 = -169.64[illegible]790231 / v coord. (m)
- U_S2-E1 = -26.400[illegible]64273 / u coord. (m)

HEADERS

- N_TELS = 4 / Number of used telescopes
- BEAMORD0= 1 / Beam order
- BEAMORD1= 3 / Beam order
- BEAMORD2= 4 / Beam order
- BEAMORD3= 5 / Beam order
- REF_TEL = 5 / Reference Telescope
- TEL_KEY = 'S1=0,S2=1,E1=2,E2=3,W1=4,W1=5' / Telescope/beam correspondence
- F_EXPLX0= 0 / Fiber explorer X coord.
- F_EXPLY0= 0 / Fiber explorer Y coord.
- F_EXPLX1= 0 / Fiber explorer X coord.
- F_EXPLY1= 0 / Fiber explorer Y coord.
- F_EXPLX2= 0 / Fiber explorer X coord.
- F_EXPLY2= 0 / Fiber explorer Y coord.
- F_EXPLX3= 0 / Fiber explorer X coord.
- F_EXPLY3= 0 / Fiber explorer Y coord.
- GDT_TRS0= 5. / GDT Threshold
- GDT_TRS1= 5. / GDT Threshold
- GDT_TRS2= 5. / GDT Threshold

HEADERS

- GDT_GAIN= 0.6 / GDT Gain
- DLOFFST0= 0. / Delay line offsets
- DLOFFST1= 0. / Delay line offsets
- …
- MANOFFS0= 0. / Delay line manual offsets
- MANOFFS1= 0. / Delay line manual offsets
- …
- ACTBAS0 = 0 / Active baselines
- ACTBAS1 = 0 / Active baselines
- …
- GDT_LOCK= 0 / Group delay track status
- CPEAK_0 = 15 / Fourier peaks position for baselines
- CPEAK0_0= 14 / Fourier peaks position for baselines
- …
- …
- BKGNDNOI= 35 / Background noise column position
- TTCOUNT0= -16.8501 / Tiptilt counts
- TTCOUNT1= 43. / Tiptilt counts
- TTCOUNT2= 36.65015 / Tiptilt counts
- TTCOUNT3= [illegible]995 / Tiptilt counts

Current Status

- Setup for 4 telescopes (move to 6?)
- Demonstrated sensitivity (Low-Res R~44)
  - H 3.5 (4.0)
  - K ~3.0 (3.5)
- We successfully tracked H band fringes using R~150 Grism (Algol)

Data Taking

- Acquire Star [5min]
- Fiber Explorer Tool [~10 min for 4 tels]
- Find all Fringes and Lock [~10 min 4 tels]
- Shutter Data (using scheduling tool)
  - Including backgrounds, foregrounds [5 minutes]
- Fringe data [5 minutes]
- Shutter Matrix [5 minutes]
- More fringes [5 minutes]
- Shutter matrix [5 minutes]

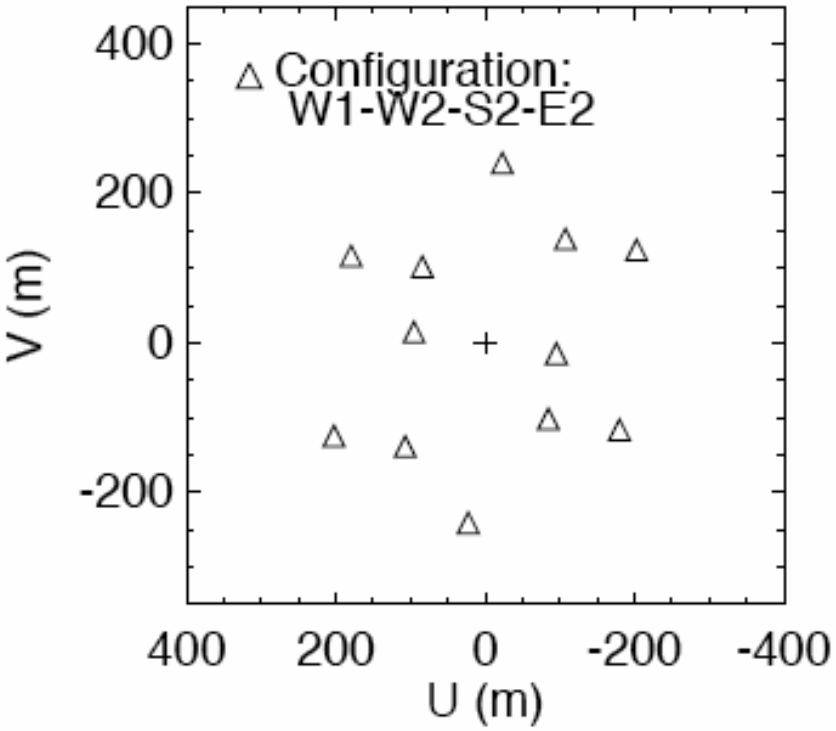
Total Time if lucky: 50 mins

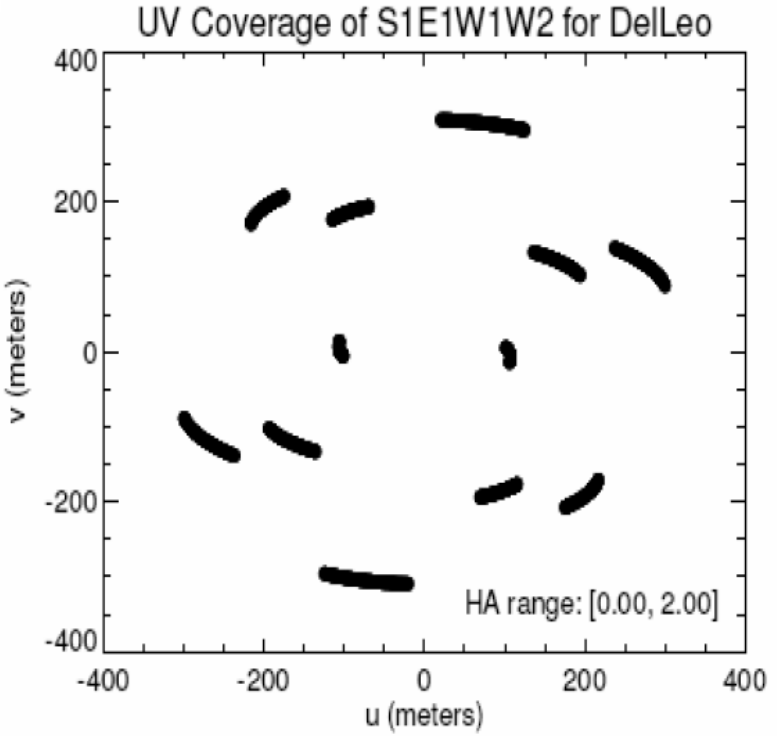
On best night we could average 1 hr per object

Why is observing with MIRC harder than CLASSIC

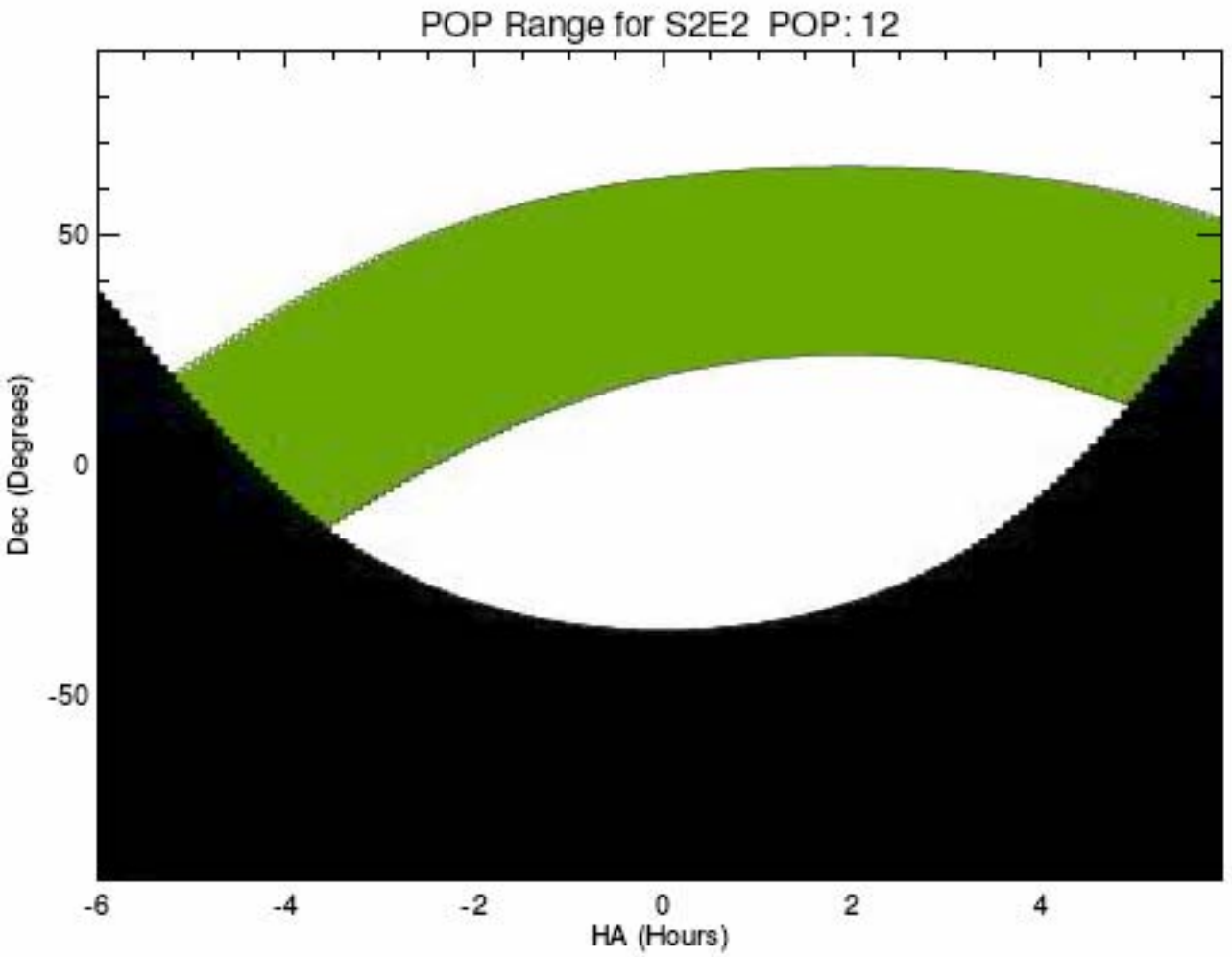
- MIRC is highly automated (this is not the problem)
- Keeping all delay carts in delay range..
  - MUCH HARDER WITH 4 TELESCOPES!
  - Limited by longest E-W baseline and THEN SOME.
- Because only a limited sky coverage is possible then also very hard to find bright calibrators

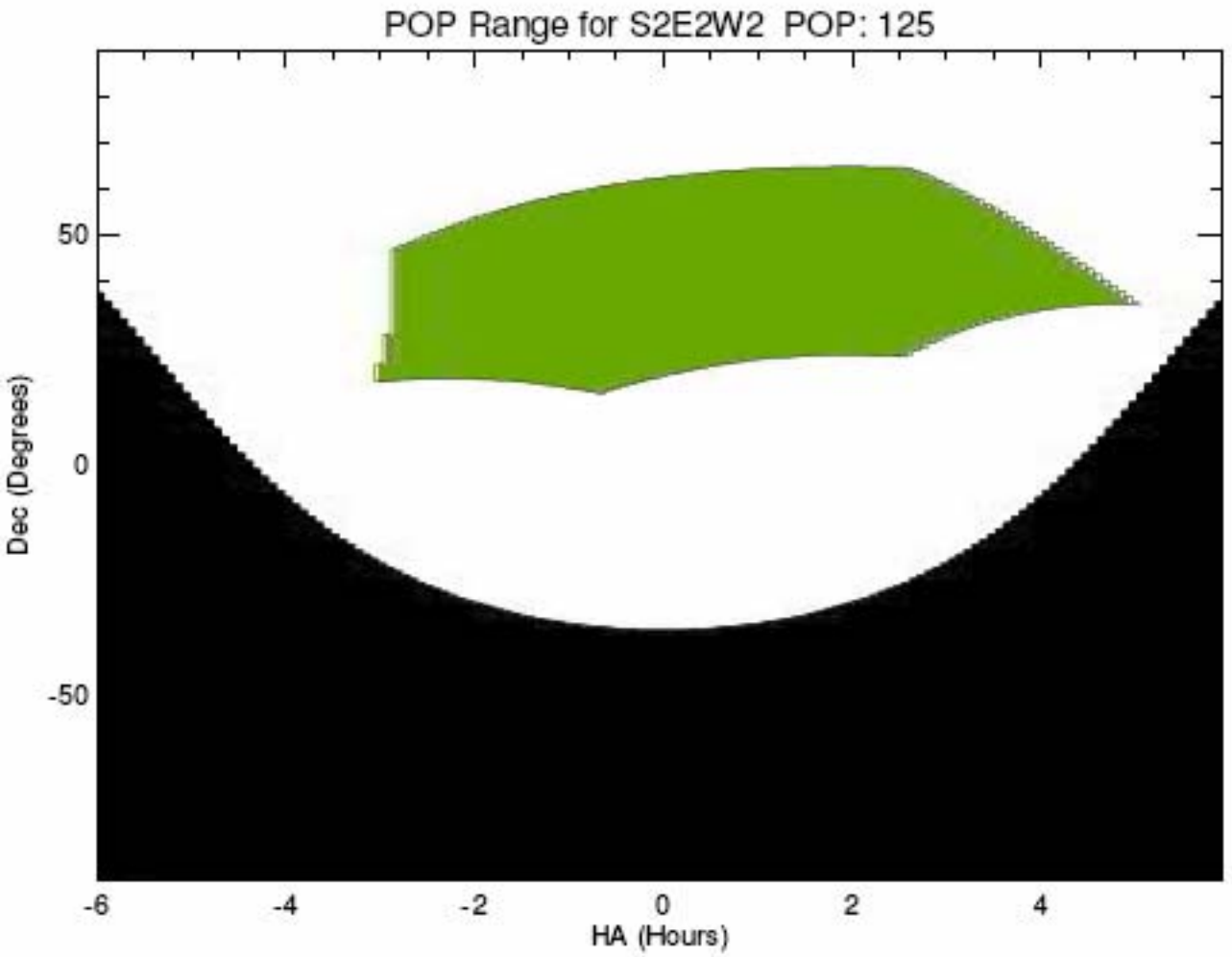
Preferred Configs: Inner-West & Outer-West

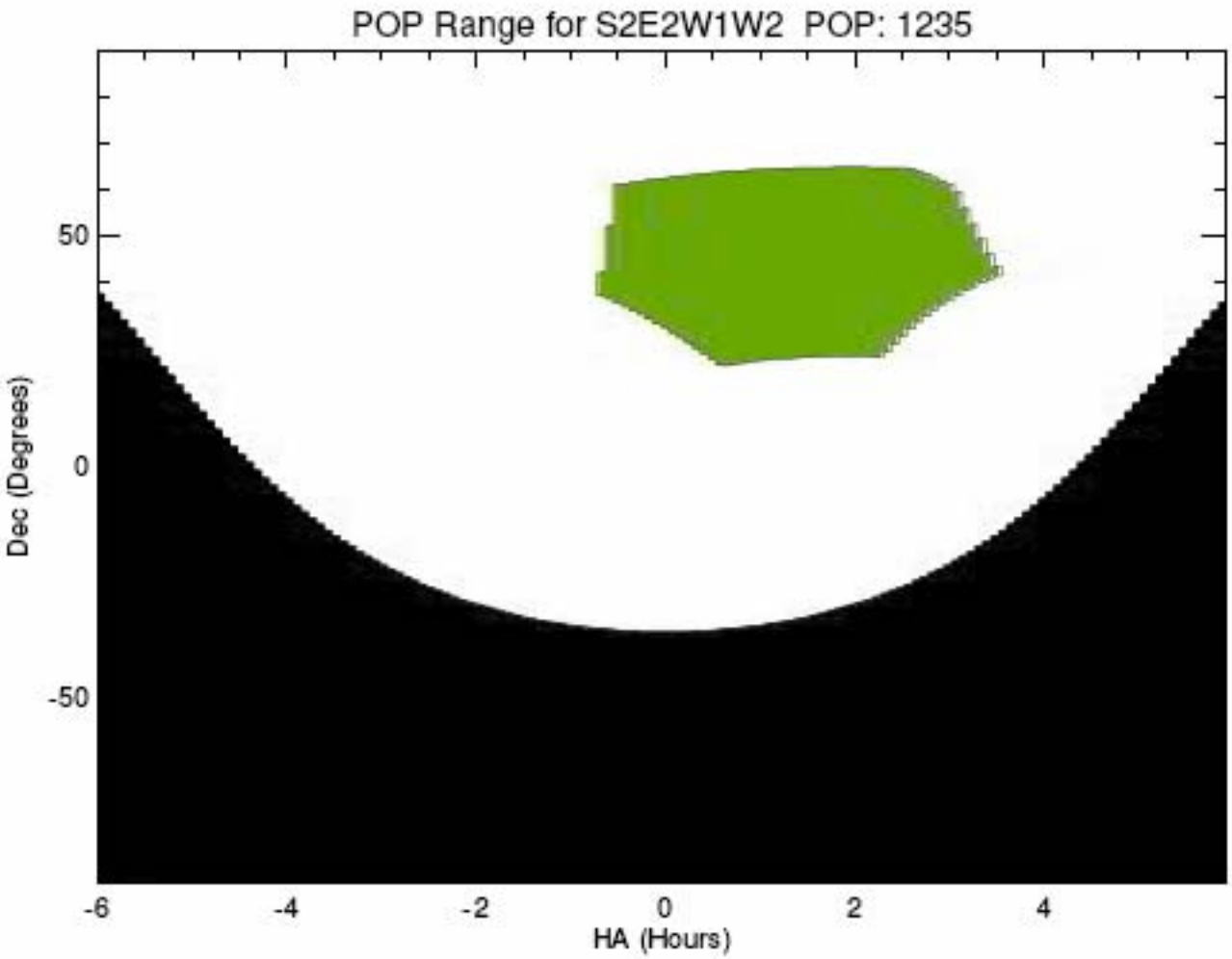


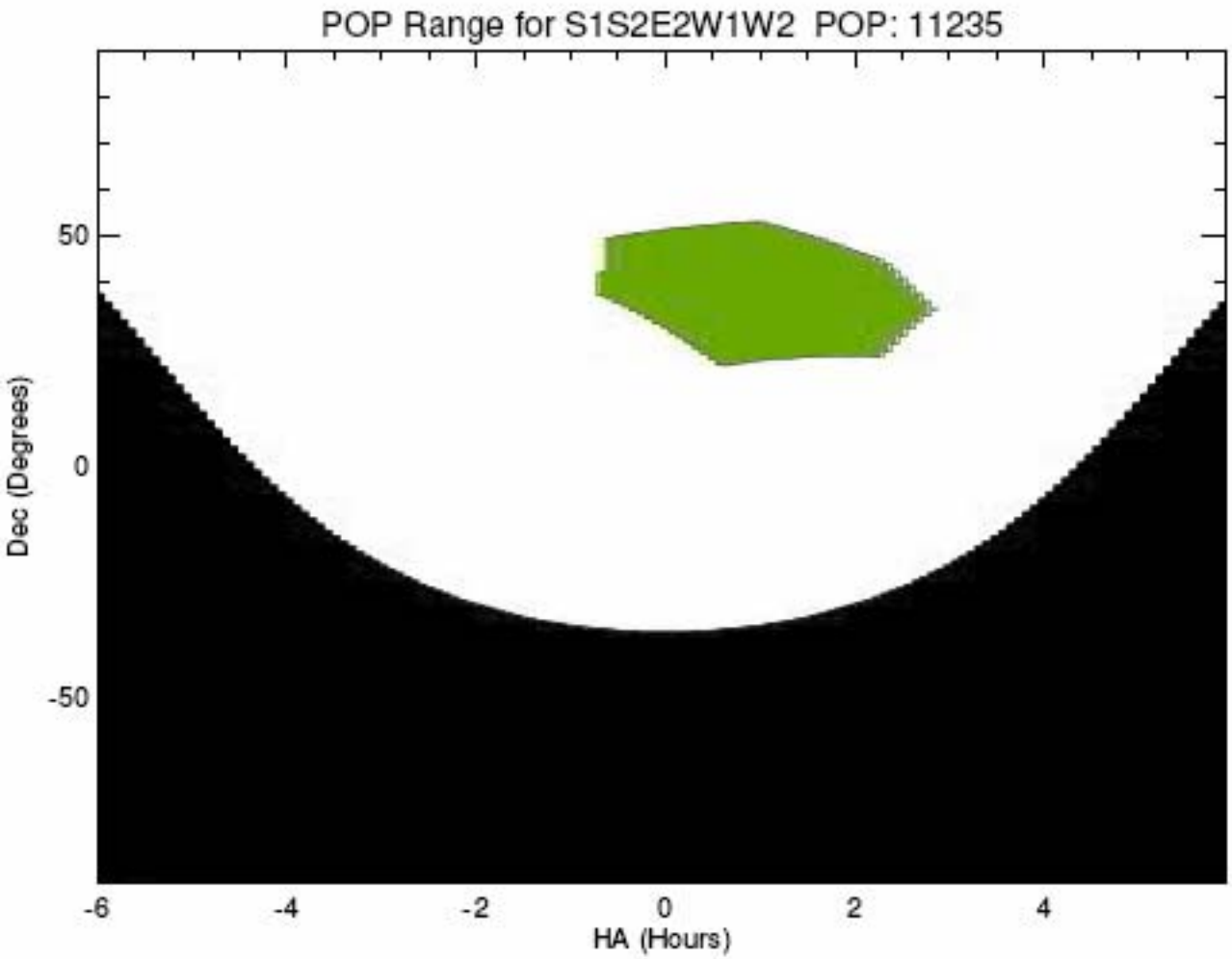


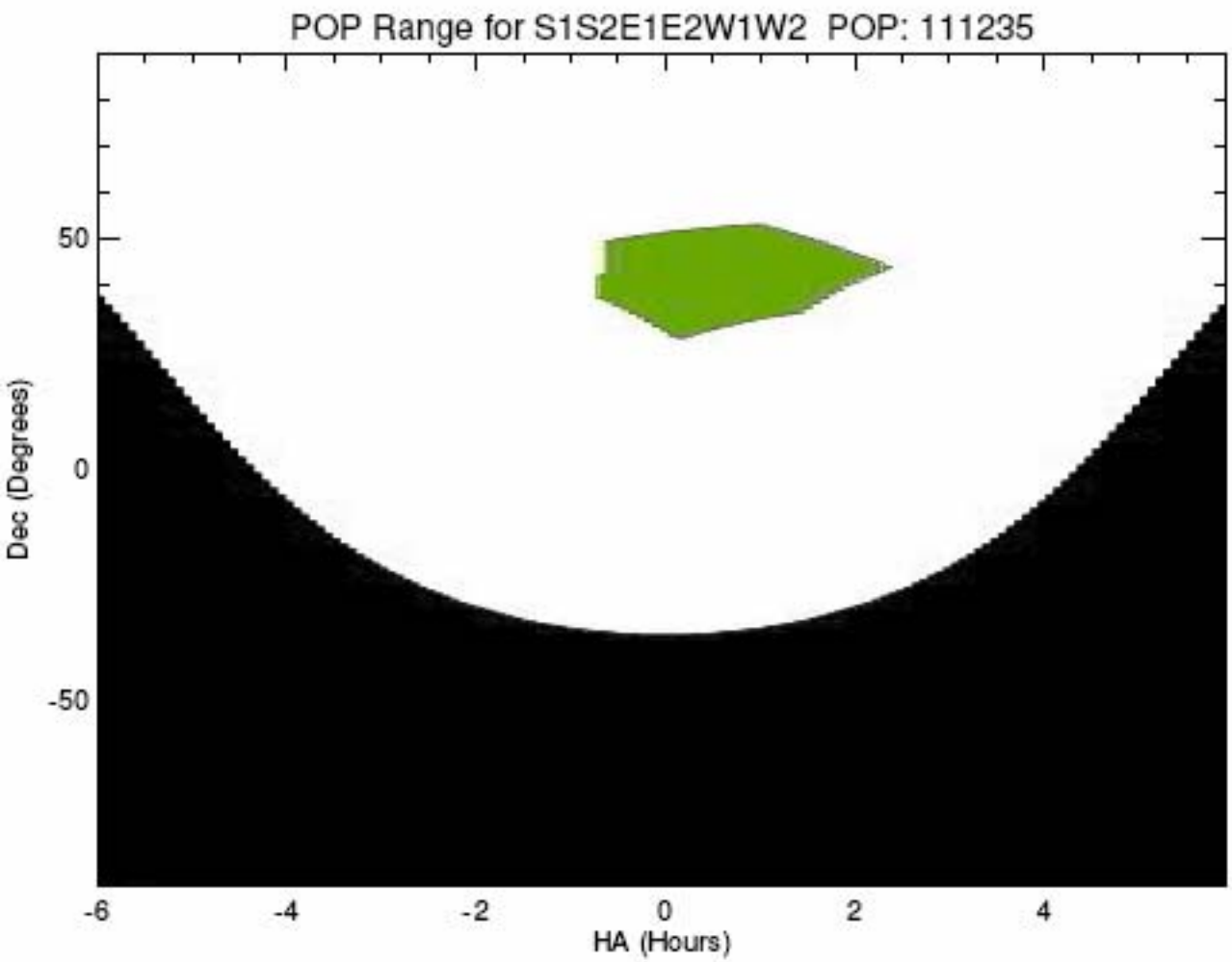
Ming Zhao calculated some sky coverage examples…

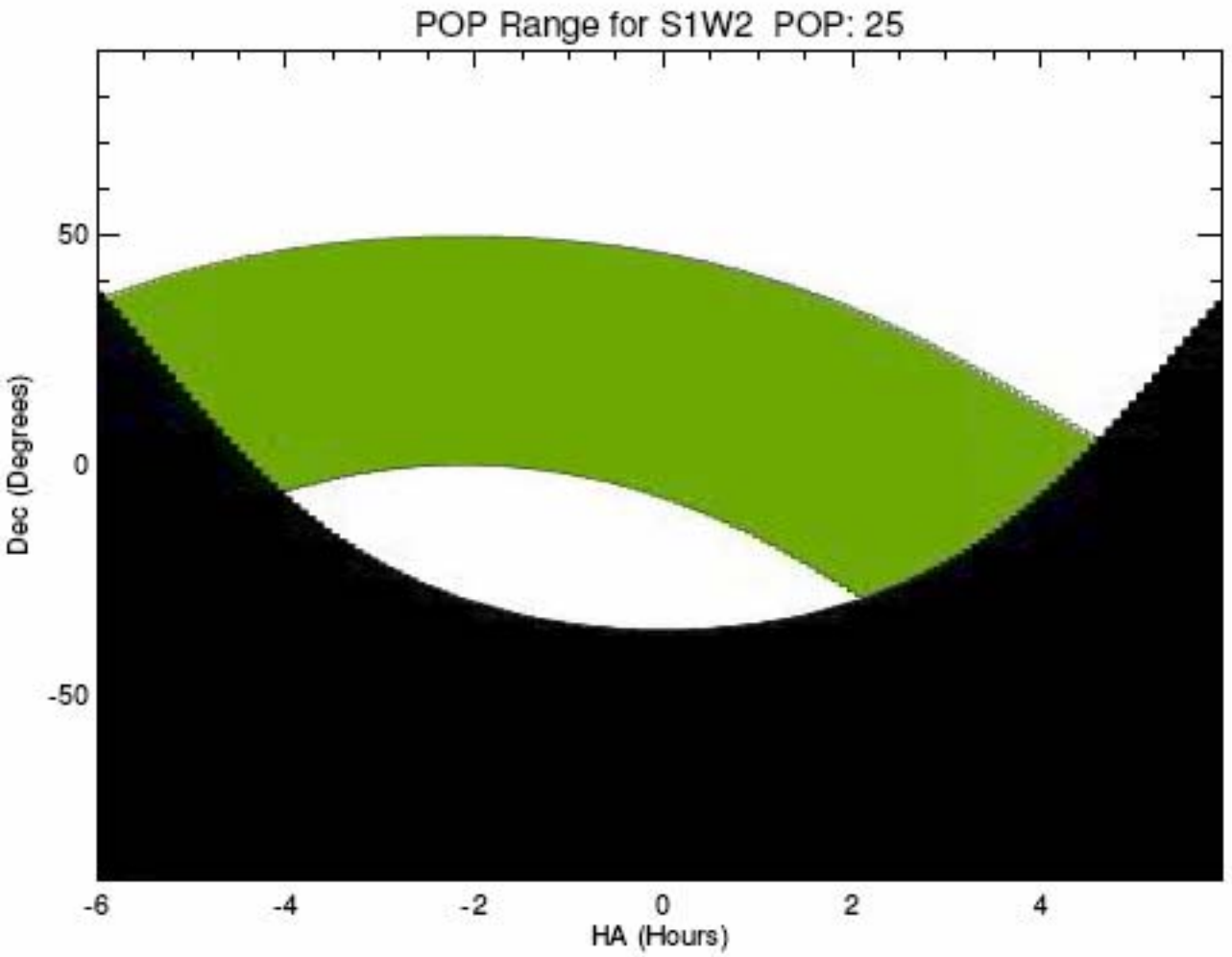


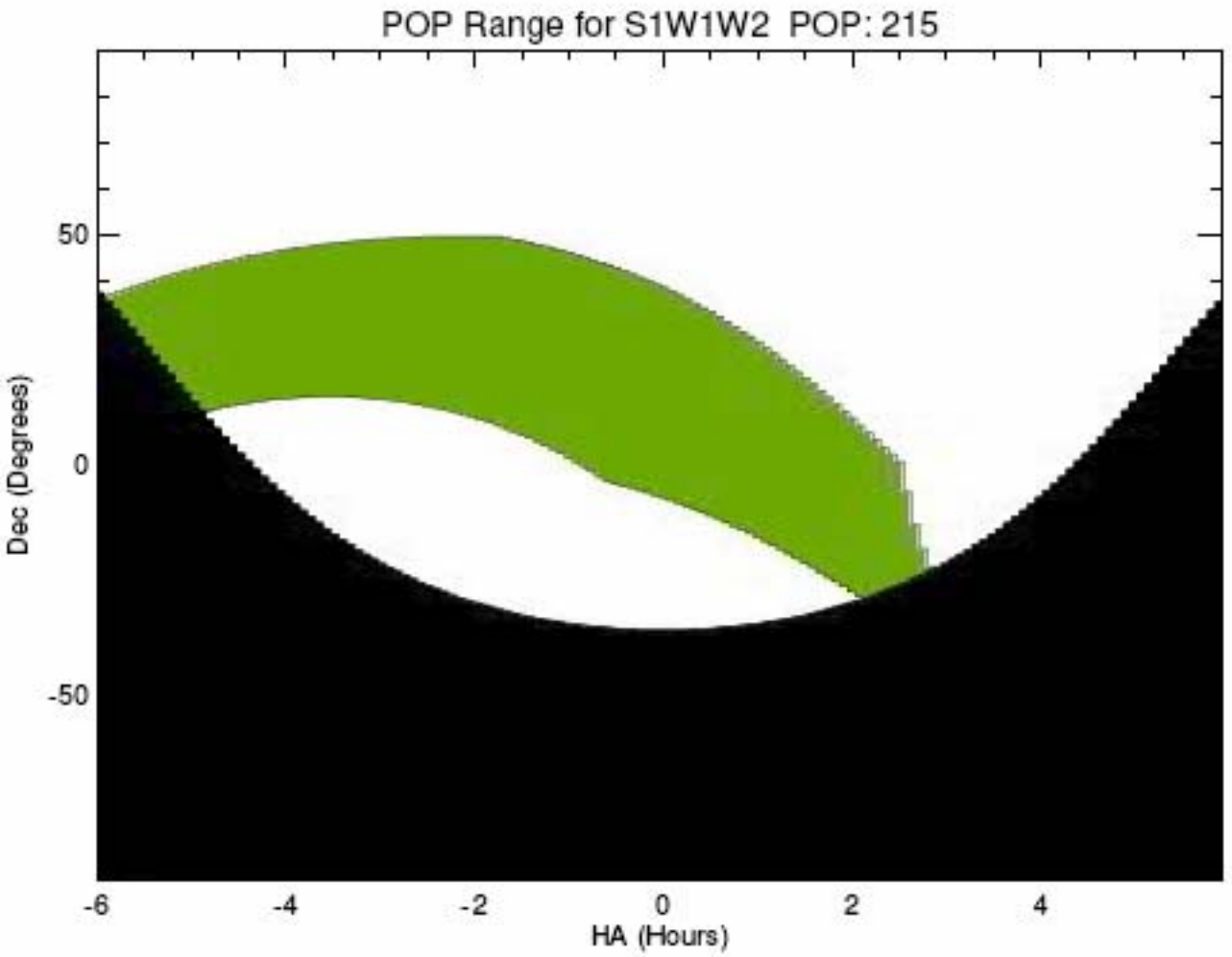

POP Range for S2E2W2 POP: 125
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)

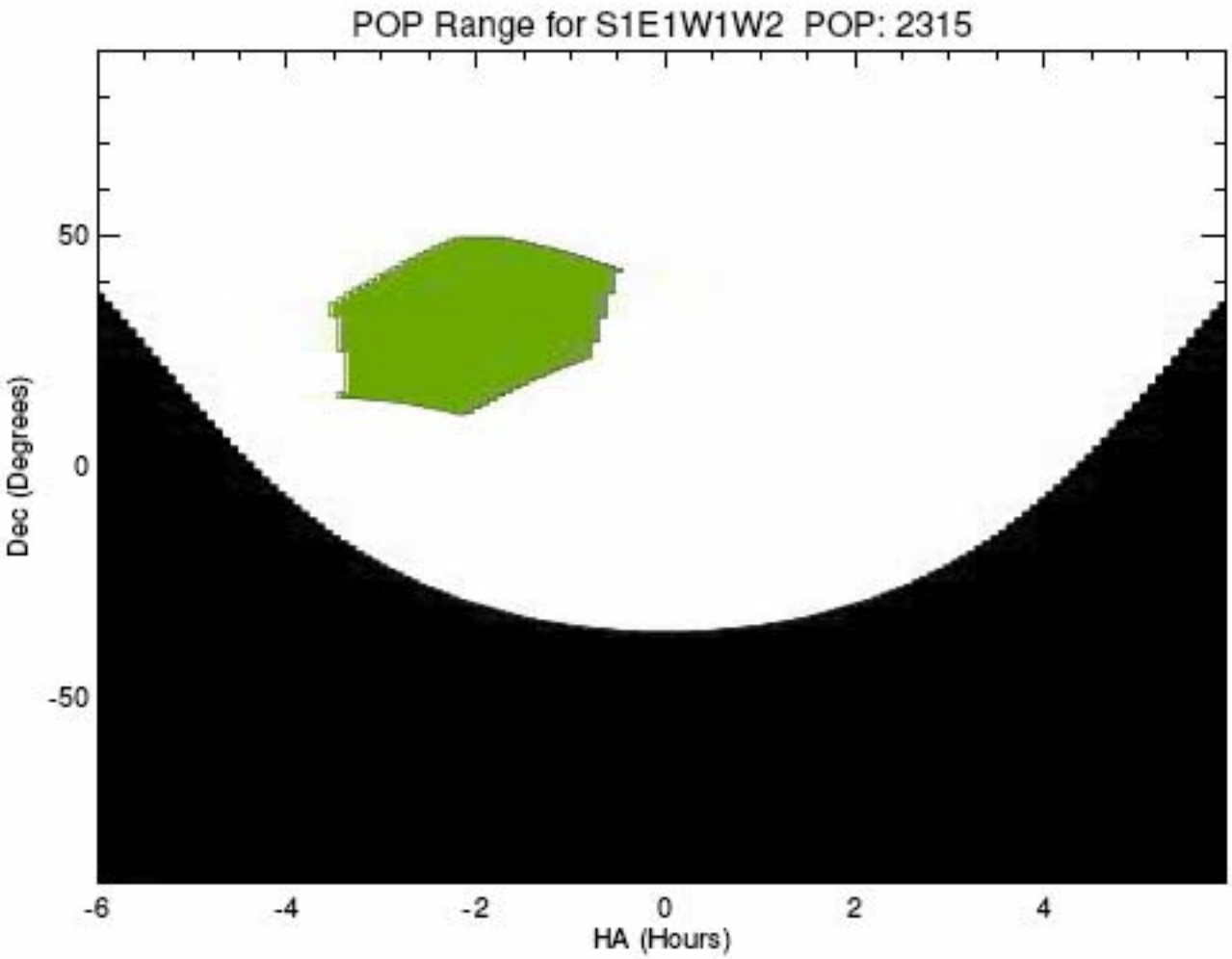

POP Range for S2E2W1W2 POP: 1235
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)

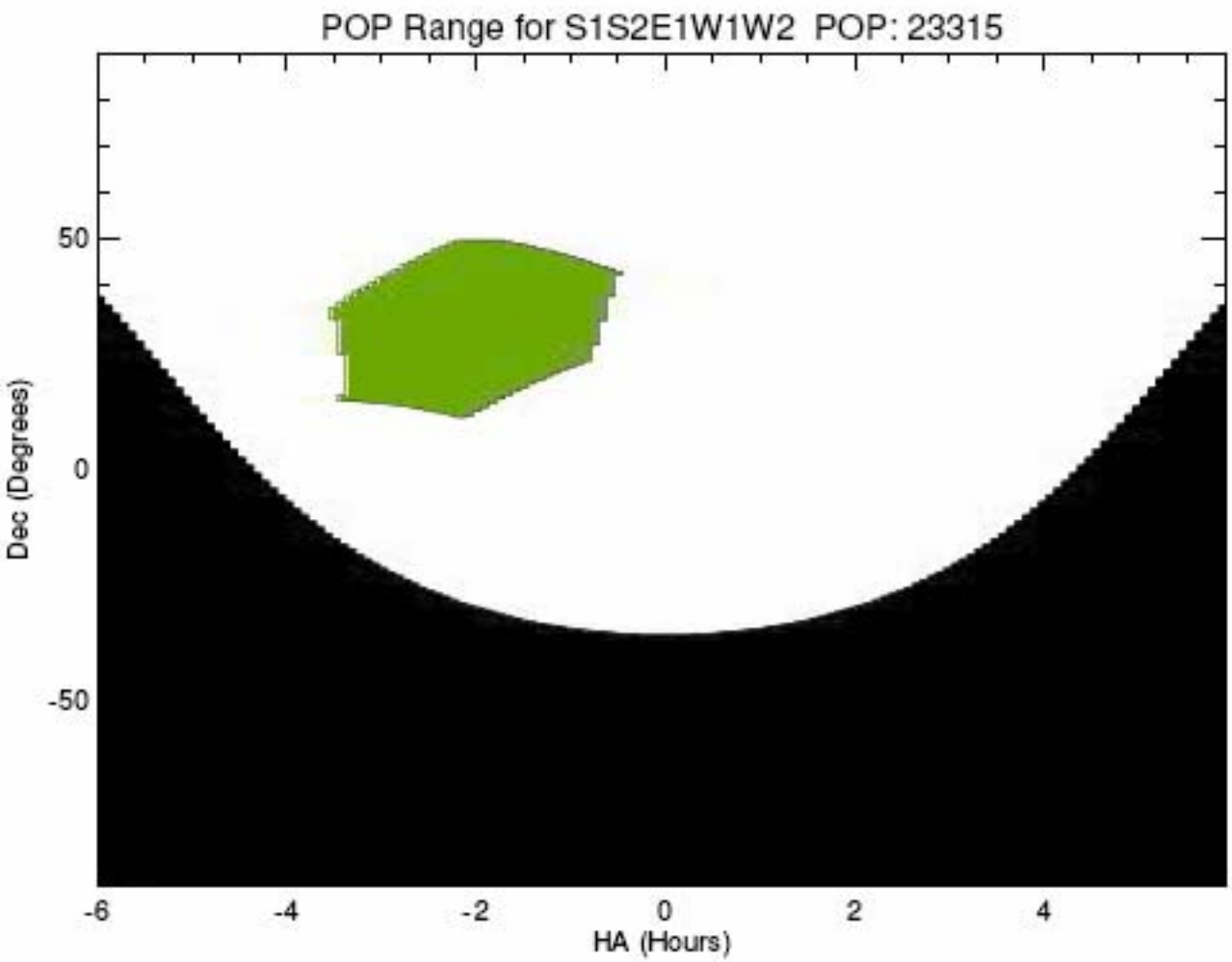

POP Range for S1S2E2W1W2 POP: 11235
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)

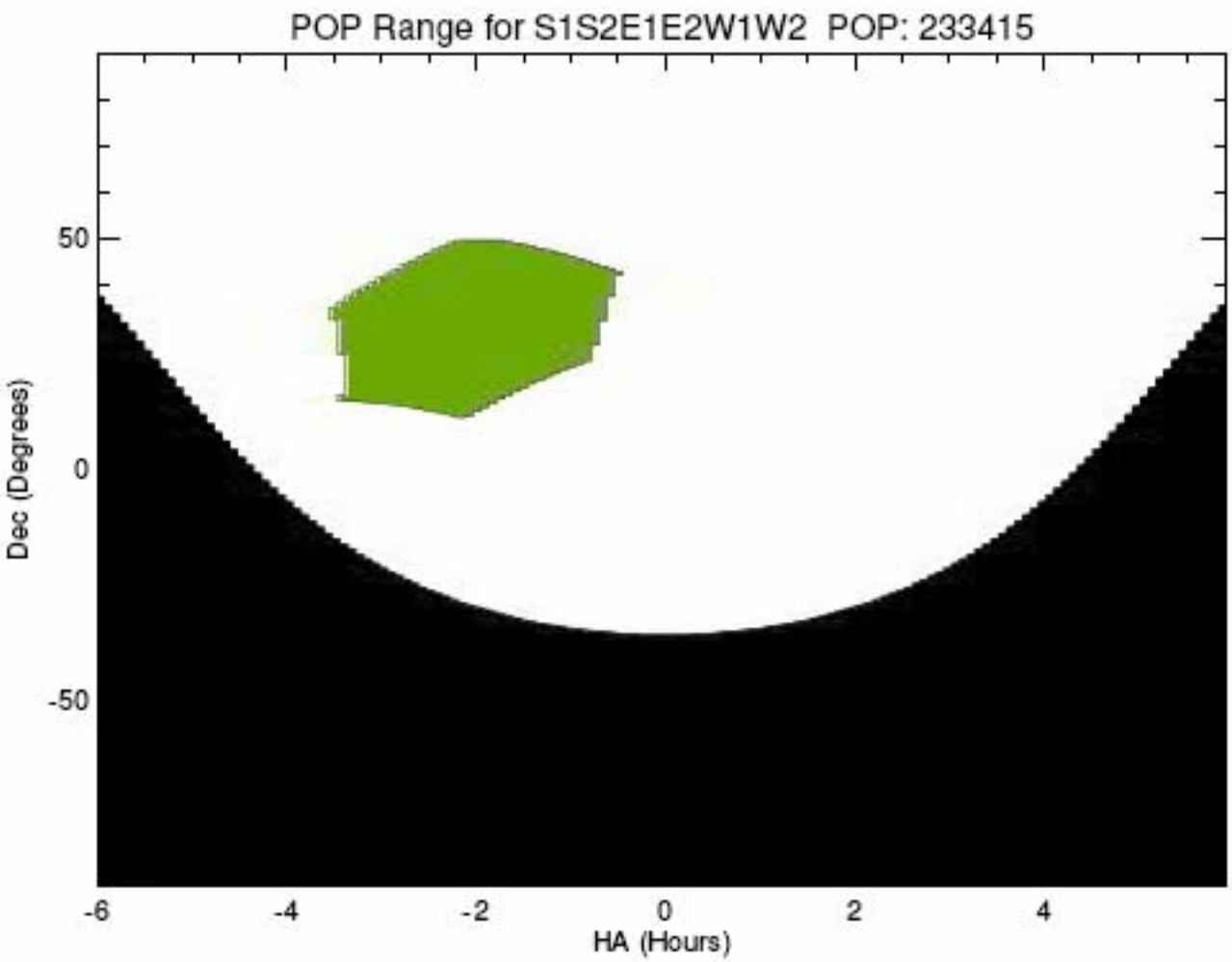

POP Range for S1S2E1E2W1W2 POP: 111235
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)


POP Range for S1W2 POP: 25
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)


POP Range for S1W1W2 POP: 215
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)


POP Range for S1E1W1W2 POP: 2315
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)


POP Range for S1S2E1W1W2 POP: 23315
50
0
-50
Dec (Degrees)
-6
-4
-2
0
2
4
HA (Hours)

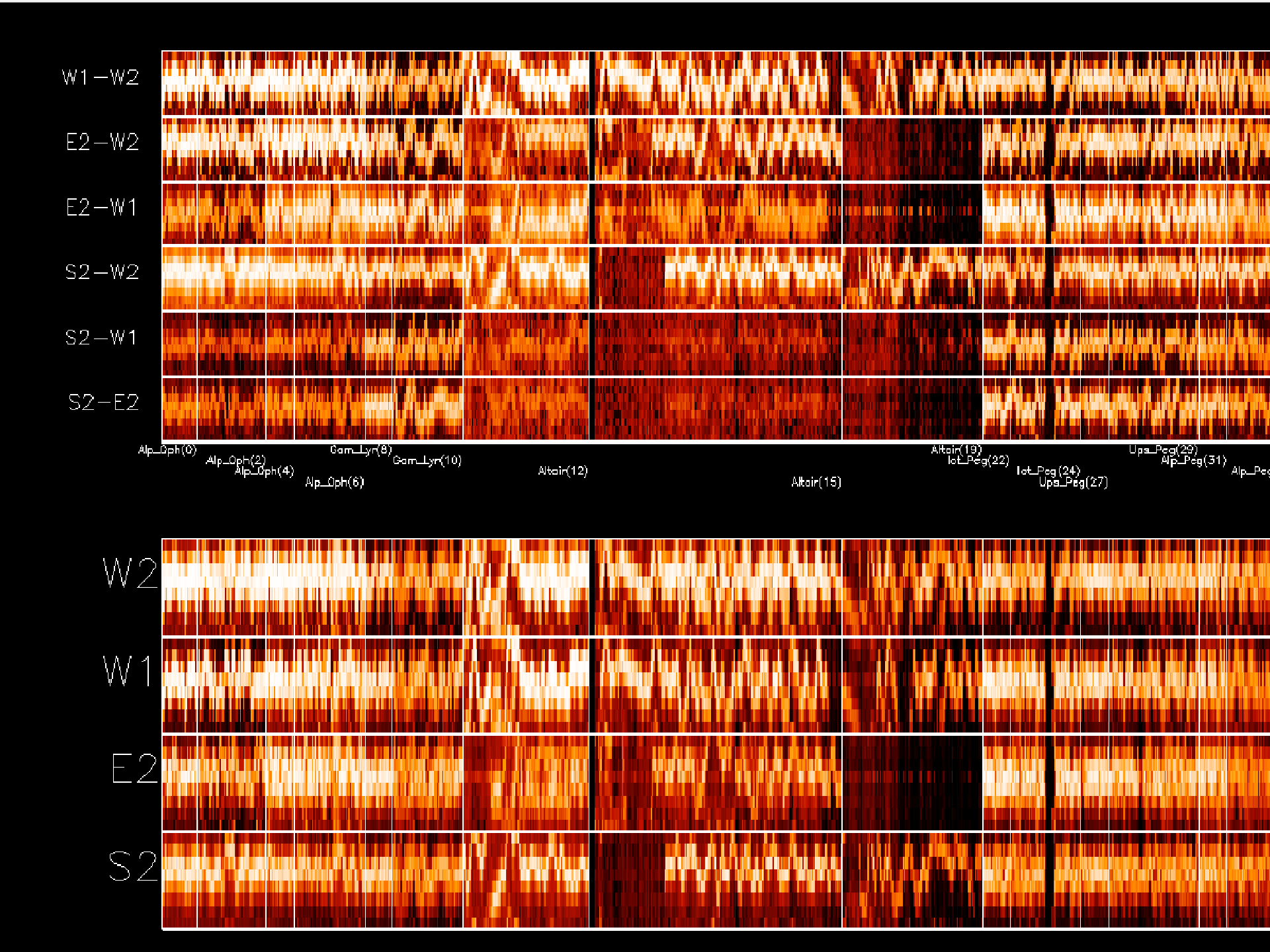

POP Range for S1S2E1E2W1W2 POP: 233415
Dec (Degrees)
50
0
-50
-6
-4
-2
0
2
4
HA (Hours)

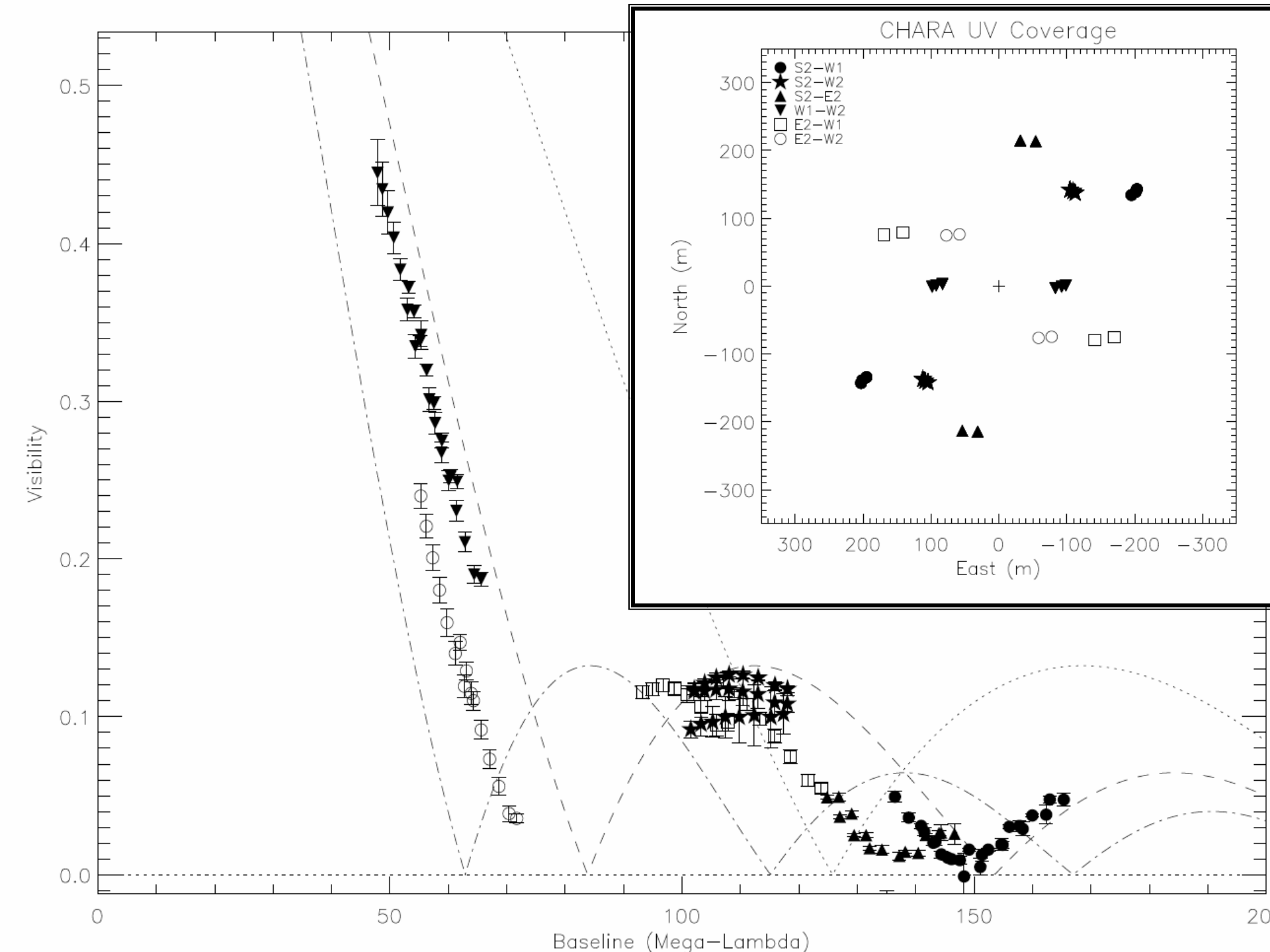
Philosophy of Data Pipeline

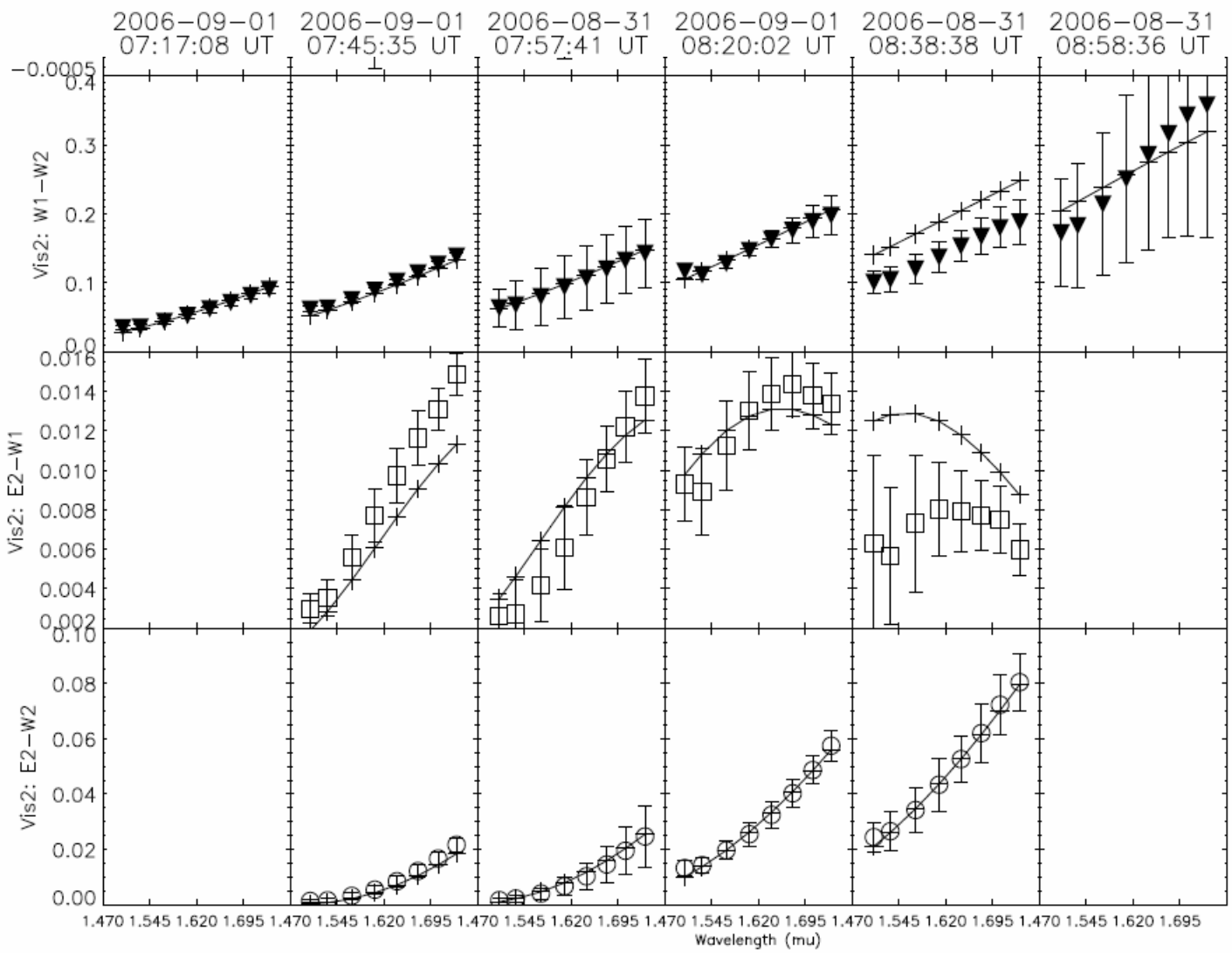
- Completely automated -- minimal user input
- Analyze an entire night at once
- Multiple calibration strategies in pipeline
- Range of data products
- Minimize options during first level of reduction
- Maximize options during last level of calibration

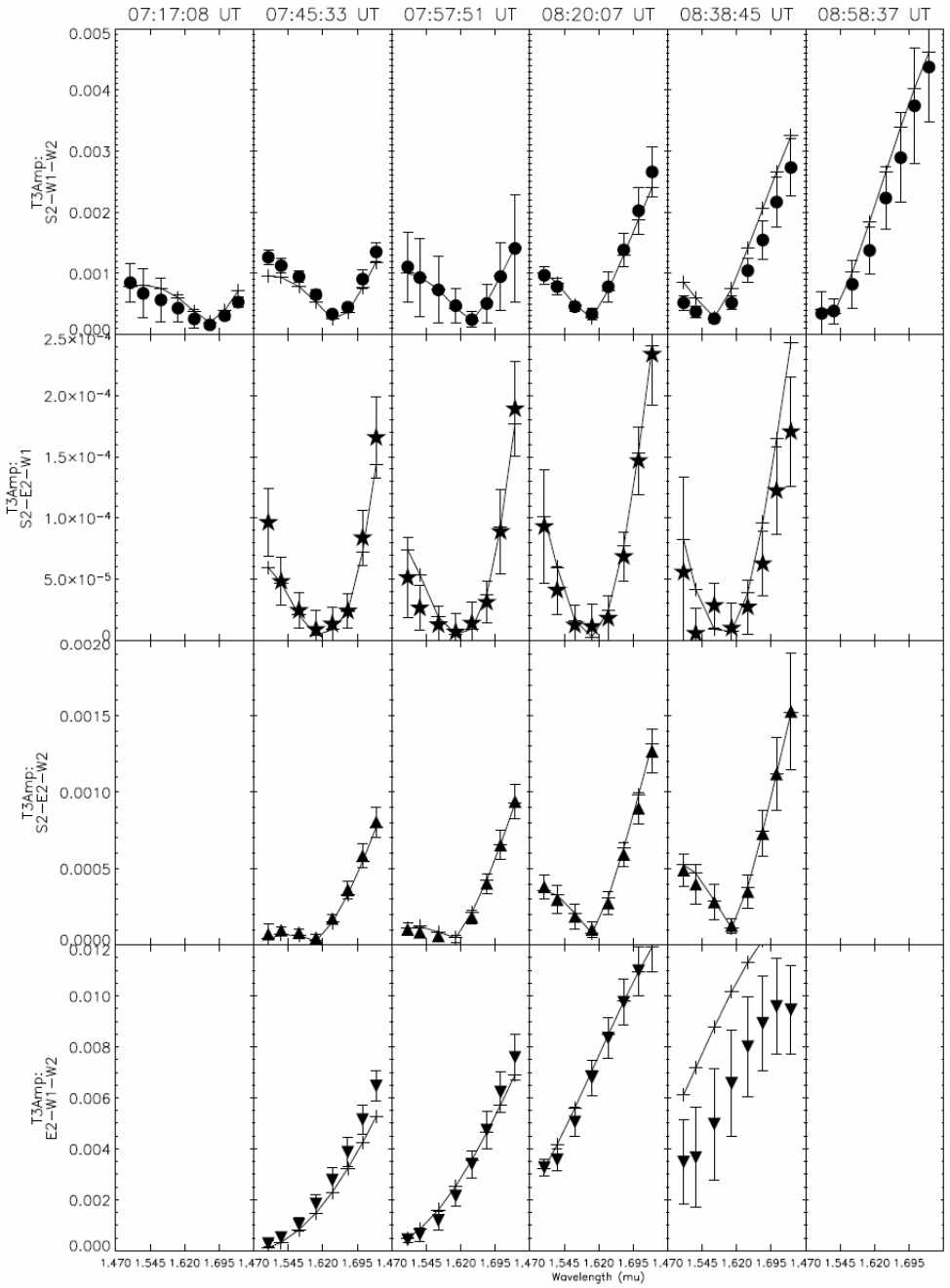
MIRC Data Pipeline

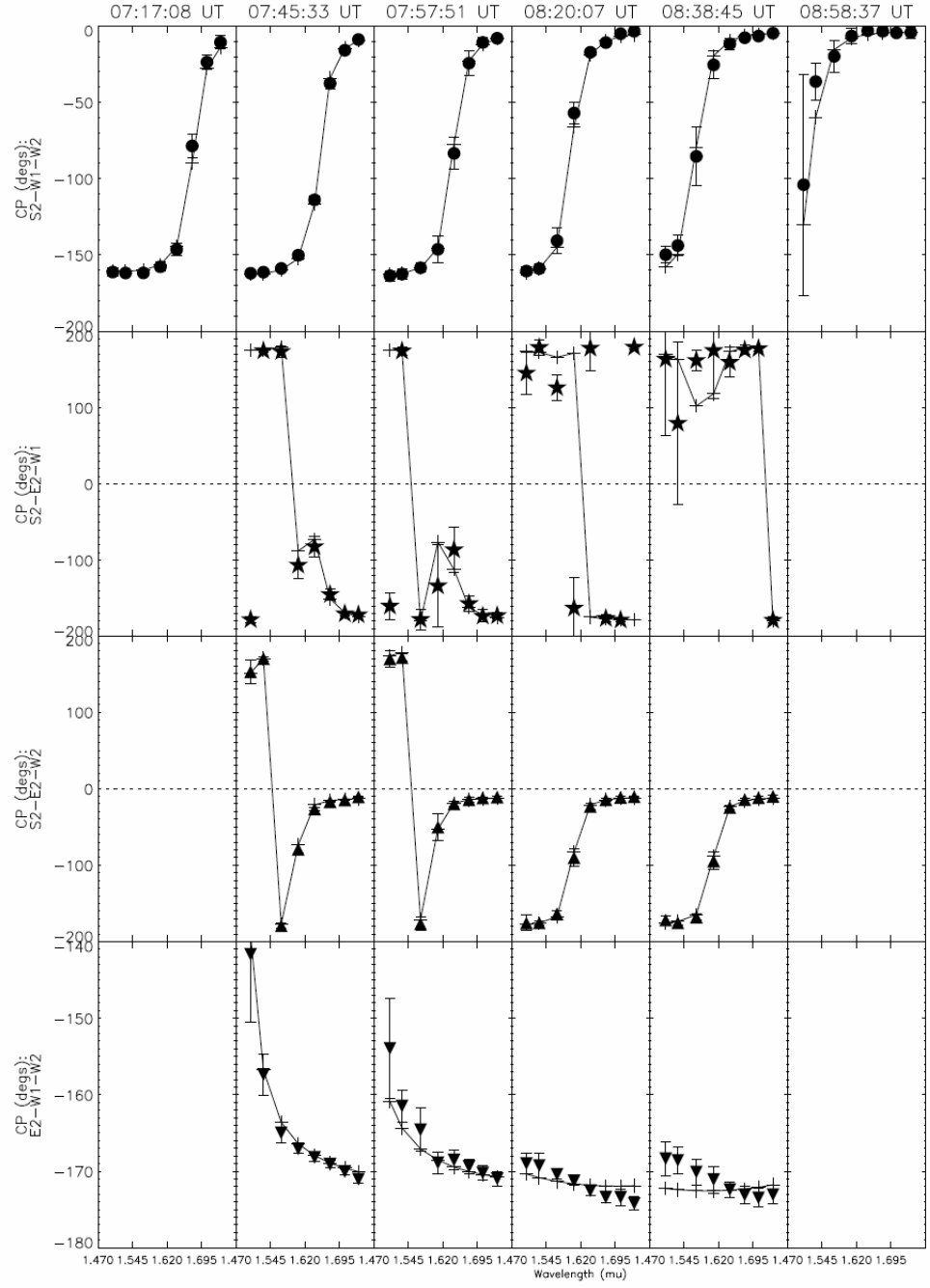
- Create mirclog, mircarray files from headers automatically
- Apply standard coadding, subframing, cleanup of camera anomalies
- Establish UV, time information from header and also internal calculations
- Analyze photometric information (shutters, choppers, fiber profile analysis)
- Establish wavelength scale from fringe fitting and applying quadratic model to spectrometer channels
- Fringe analysis -- powerspectrum, triple amplitude and closure phase, (differential phase), (closure amplitude), (coherent estimators), (temporal coherence time) Run the interactive 'mirc_reduce' script
  - Choose target cals w/ diameters
  - Choose averaging method (split data up into chunks)
  - Edit data to find lost fringes
  - Inspect data in detail
  - Save reduced data in a FULL OI-FITS data format
- Create summary plots for inspecting full richness of data
- Imaging
  - MACIM (Ireland), CLEAN (development/Zhao), BSMEM (soon.. John Young)


W1−W2
E2−W2
E2−W1
S2−W2
S2−W1
S2−E2
Alp_Oph(0)
Alp_Oph(2)
Alp_Oph(4)
Alp_Oph(6)
Gam_Lyr(8)
Gam_Lyr(10)
Altair(12)
Altair(15)
Altair(19)
Iot_Peg(22)
Iot_Peg(24)
Upa_Peg(27)
Upa_Peg(29)
Alp_Peg(31)
W2
W1
E2
S2


CHARA UV Coverage
S2–W1
S2–W2
S2–E2
W1–W2
E2–W1
E2–W2
North (m)
East (m)
300
200
100
0
−100
−200
−300
Visibility
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
Baseline (Mega–Lambda)

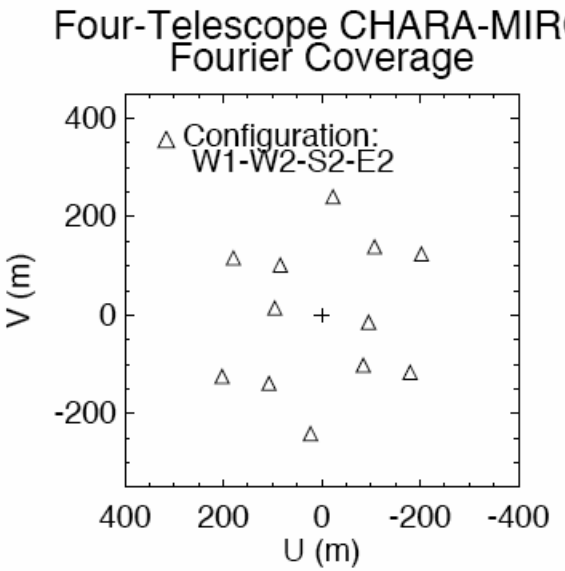

2006-09-01 07:17:08 UT
2006-09-01 07:45:35 UT
2006-08-31 07:57:41 UT
2006-09-01 08:20:02 UT
2006-08-31 08:38:38 UT
2006-08-31 08:58:36 UT
Vis2: W1-W2
Vis2: E2-W1
Vis2: E2-W2
Wavelength (mu)
1.470 1.545 1.620 1.695

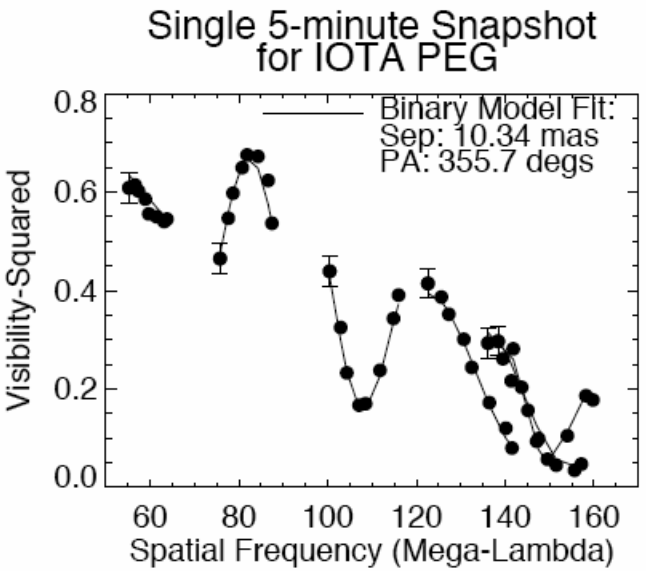

07:17:08 UT
07:45:33 UT
07:57:51 UT
08:20:07 UT
08:38:45 UT
08:58:37 UT
T3Amp: S2−W1−W2
T3Amp: S2−E2−W1
T3Amp: S2−E2−W2
T3Amp: E2−W1−W2
1.470 1.545 1.620 1.695
Wavelength (mu)

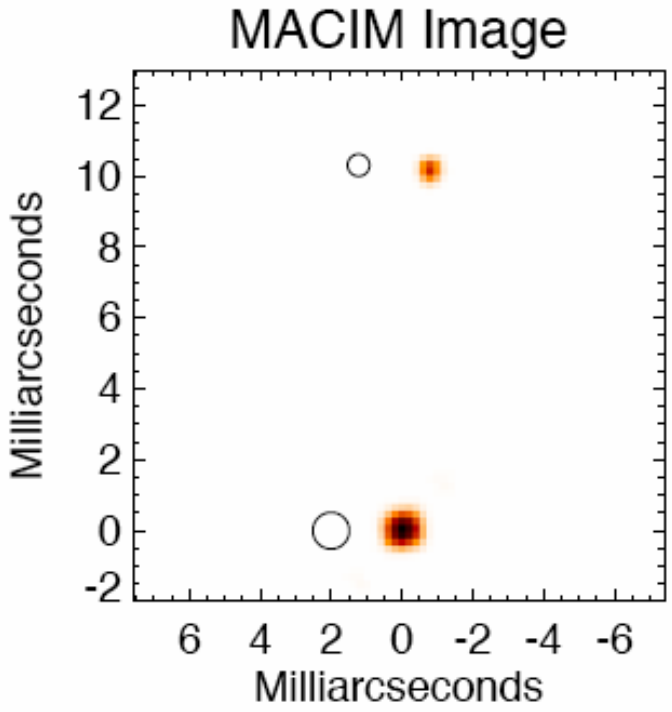

07:17:08 UT
07:45:33 UT
07:57:51 UT
08:20:07 UT
08:38:45 UT
08:58:37 UT
CP (degs): S2−W1−W2
CP (degs): S2−E2−W1
CP (degs): S2−E2−W2
CP (degs): E2−W1−W2
Wavelength (mu)

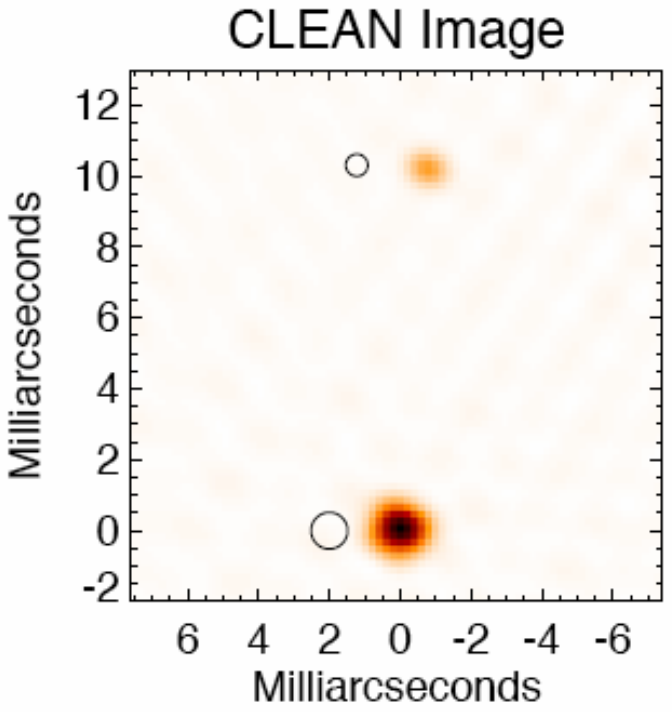
Validation

- Pipeline carefully checked against the binary IOTA Peg
  - Still some visibility calibration ‘issues’
  - Always advise getting 2 or 3 visits on each target due to visibility calibration problems


Four-Telescope CHARA-MIRC
Fourier Coverage
Configuration:
W1-W2-S2-E2
V (m)
U (m)
400
200
0
-200
-400


Single 5-minute Snapshot
for IOTA PEG
Binary Model Fit:
Sep: 10.34 mas
PA: 355.7 degs
Visibility-Squared
Spatial Frequency (Mega-Lambda)
0.0
0.2
0.4
0.6
0.8
60
80
100
120
140
160


MACIM Image
Milliarcseconds
12
10
8
6
4
2
0
-2
6 4 2 0 -2 -4 -6
Milliarcseconds


CLEAN Image
Milliarcseconds
12
10
8
6
4
2
0
-2
6 4 2 0 -2 -4 -6
Milliarcseconds

Imaging Campaigns 2007-

Due to complexities of scheduling, competition from NPOI, and benefit of joining resources, MIRC group at UM proposes to organize MIRC observations in imaging "campaigns."

In a campaign, only a few objects at similar declinations are observed using a few configurations for IMAGING.

For interacting binaries, the imaging will occur over an entire orbit.

We are developing a list of targets and sponsors…(next talk tomorrow) -- ADOPT ONE TODAY!

Current observing philosophy

- "Shared risk" mode
- Due to scheduling complexities, mirc proposals will be multi-plexed within observing blocks
- While in the future, CHARA observers can run MIRC just fine, it may always be necessary to have a detailed schedule by the "MIRC Experts"
- For this year, JDM +MZ will take responsibility for scheduling and trying to get data for everyone in the face of the inevitable weather and instrument and interferometer unknowns… be optimistic