Polarinterferometry with MIRC-X

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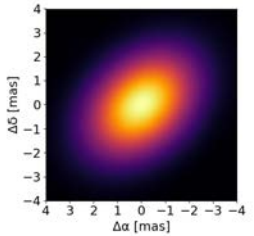
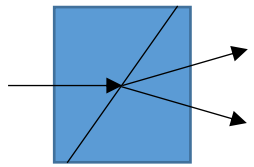
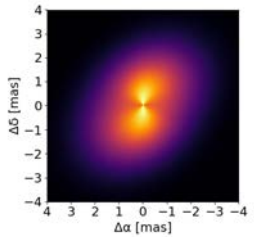
Science cases for H-band polarinterferometry

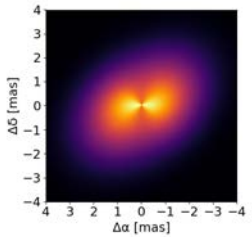
- Dust distribution in YSO inner disks
- Dust shells around evolved stars
  - Mira variable stars
  - Betelgeuse
  - AGB star shells
- Thomson scattering in Be Stars



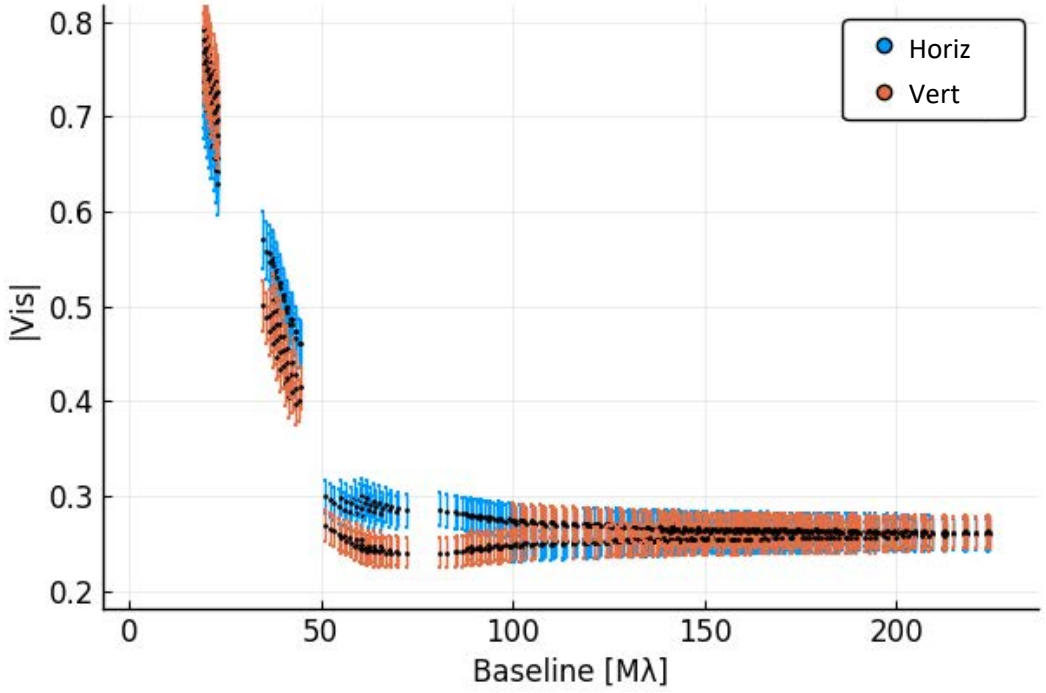


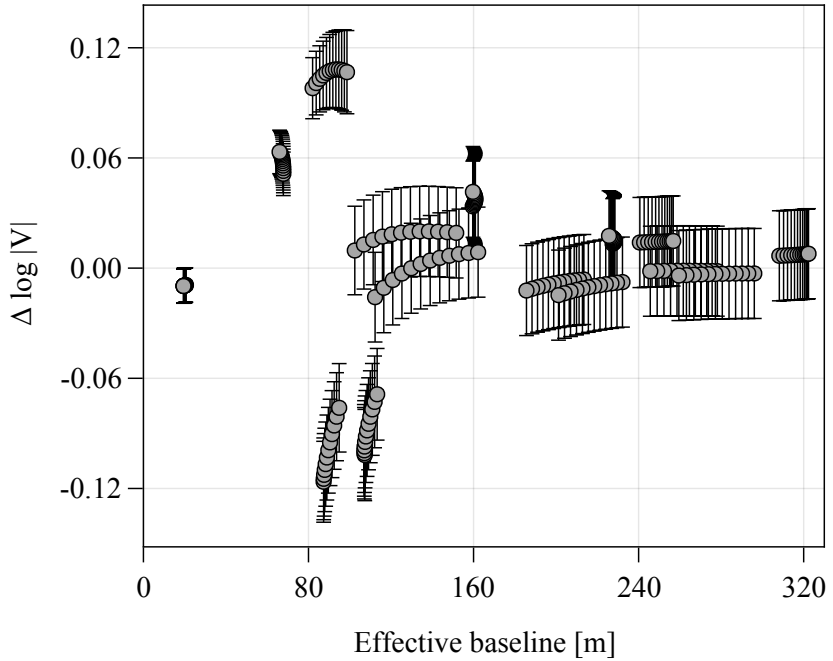


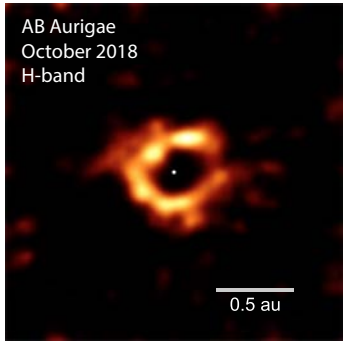
Horizontal



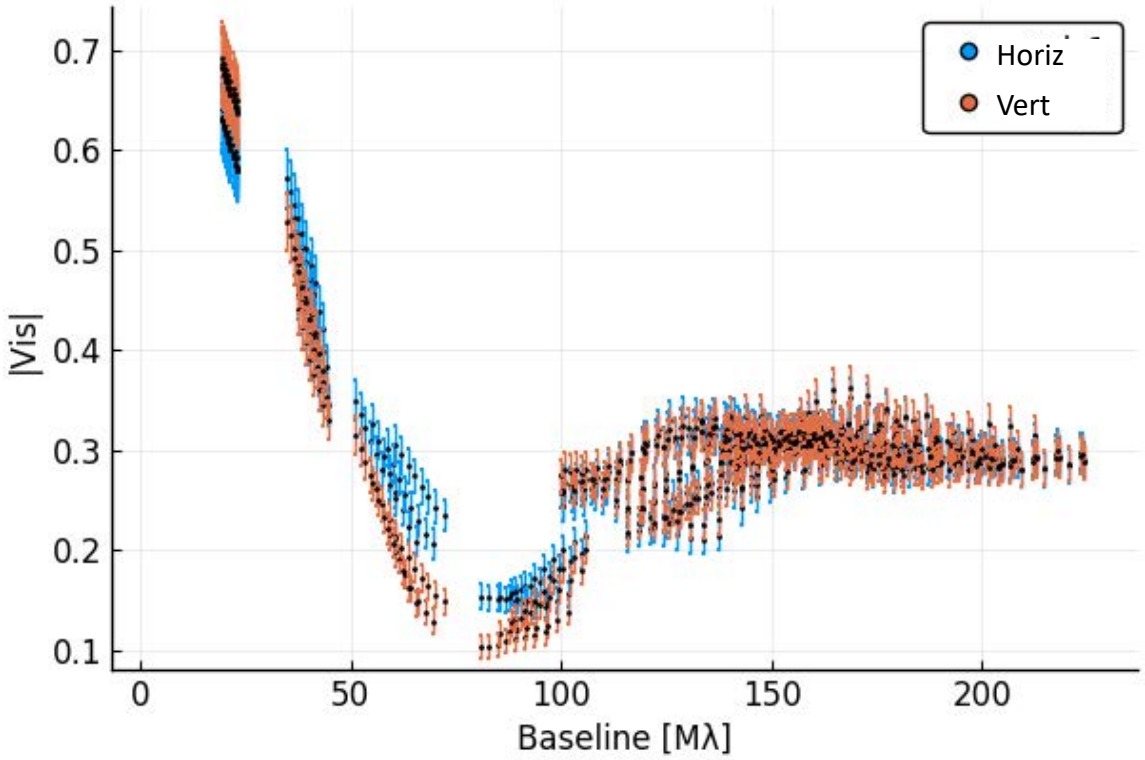
Vertical

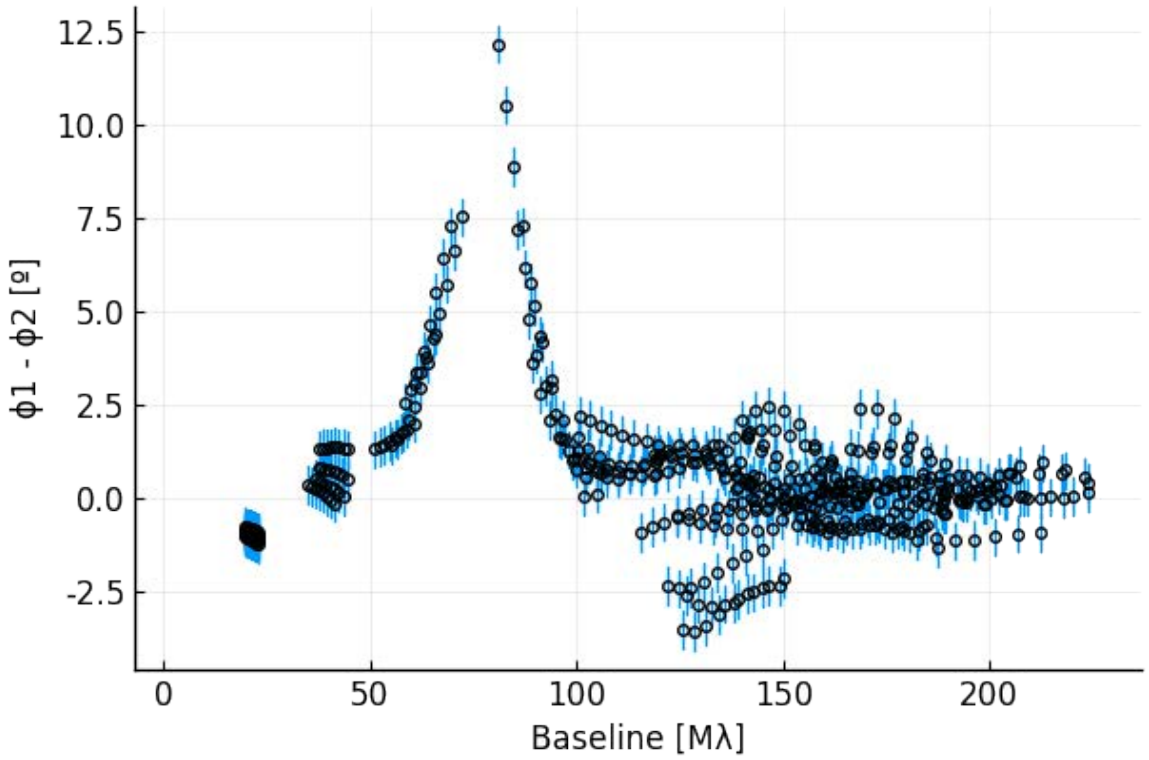


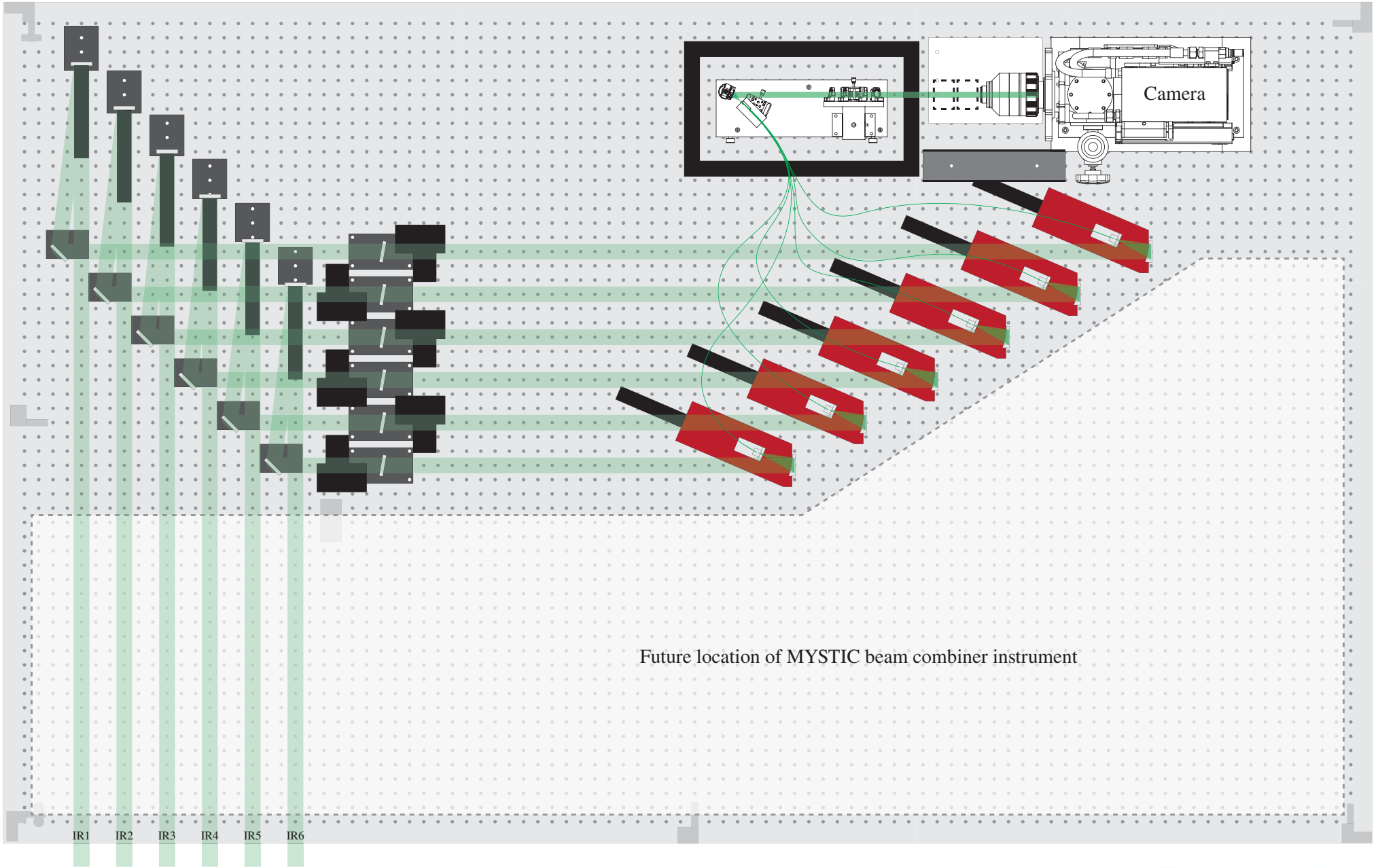


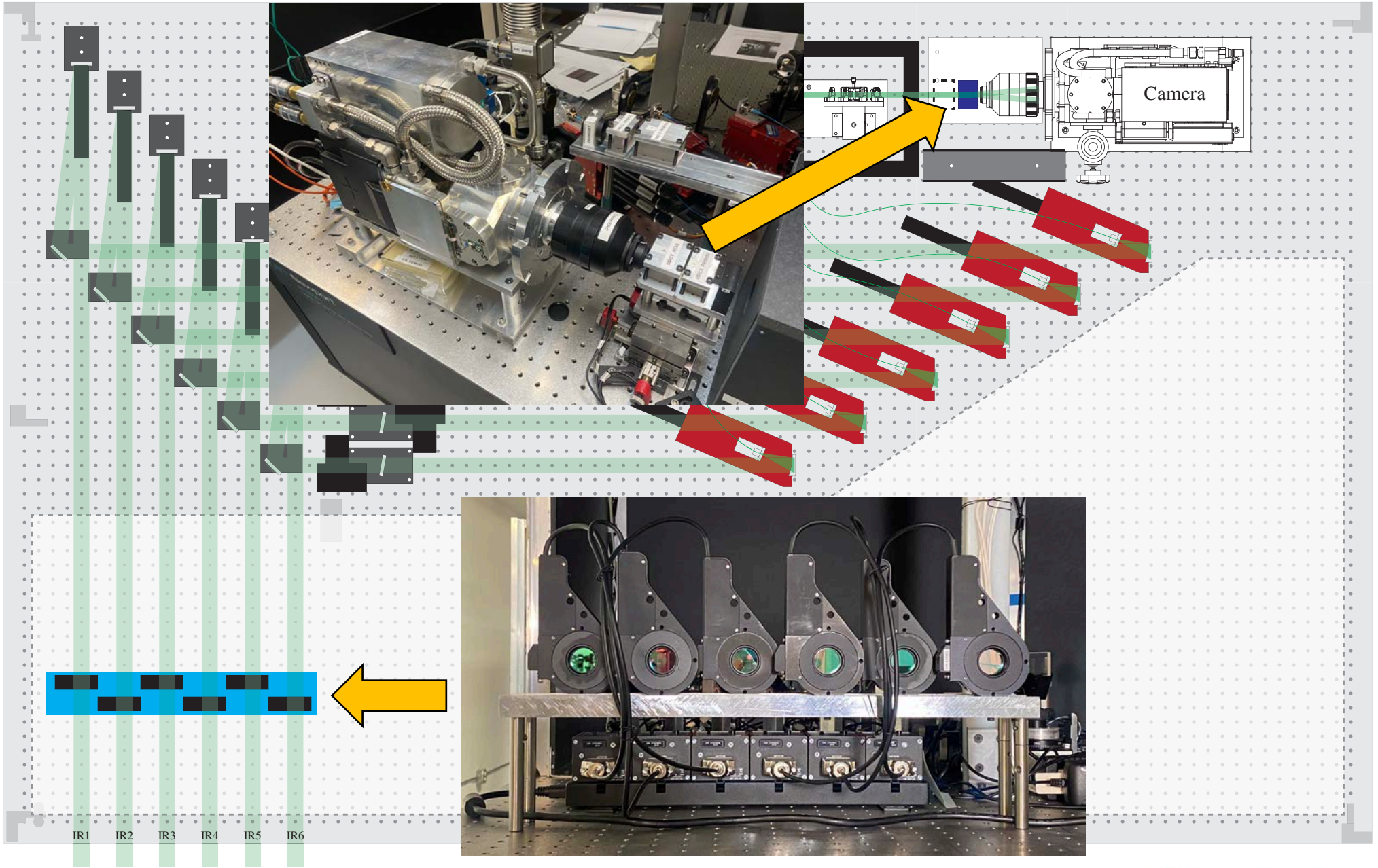


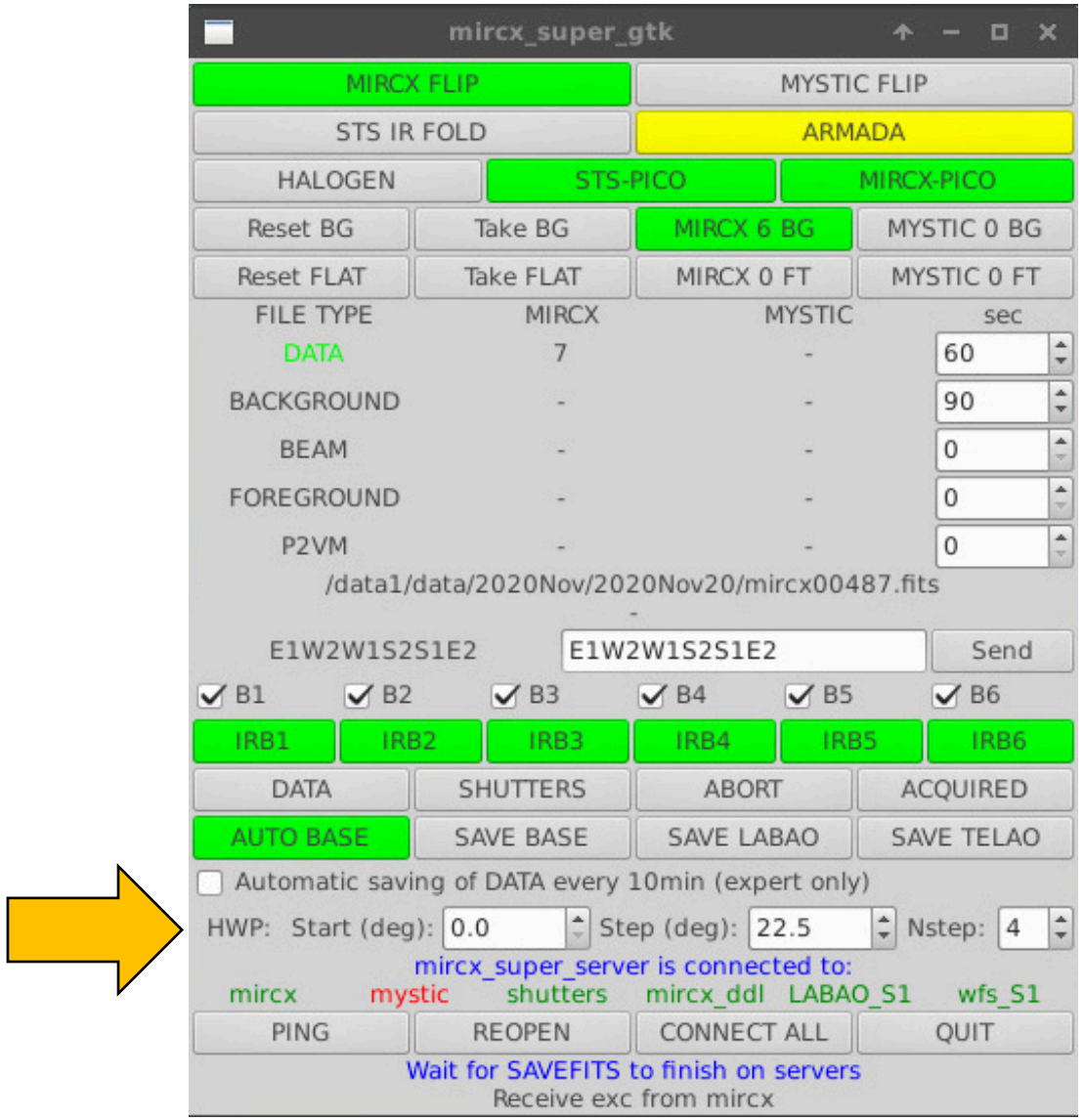
with 20% azimuthal polarization






Camera
Future location of MYSTIC beam combiner instrument
IR1
IR2
IR3
IR4
IR5
IR6


Camera
IR1
IR2
IR3
IR4
IR5
IR6


mircx_super_gtk
MIRCX FLIP
MYSTIC FLIP
STS IR FOLD
ARMADA
HALOGEN
STS-PICO
MIRCX-PICO
Reset BG
Take BG
MIRCX 6 BG
MYSTIC 0 BG
Reset FLAT
Take FLAT
MIRCX 0 FT
MYSTIC 0 FT
FILE TYPE
MIRCX
MYSTIC
sec
DATA
7
-
60
BACKGROUND
-
-
90
BEAM
-
-
0
FOREGROUND
-
-
0
P2VM
-
-
0
/data1/data/2020Nov/2020Nov20/mircx00487.fits
-
E1W2W1S2S1E2
E1W2W1S2S1E2
Send
B1
B2
B3
B4
B5
B6
IRB1
IRB2
IRB3
IRB4
IRB5
IRB6
DATA
SHUTTERS
ABORT
ACQUIRED
AUTO BASE
SAVE BASE
SAVE LABAO
SAVE TELAO
Automatic saving of DATA every 10min (expert only)
HWP: Start (deg): 0.0
Step (deg): 22.5
Nstep: 4
mircx_super_server is connected to:
mircx
mystic
shutters
mircx_ddl
LABAO_S1
wfs_S1
PING
REOPEN
CONNECT ALL
QUIT
Wait for SAVEFITS to finish on servers
Receive exc from mircx

Instrumental calibration

- Large AOI reflections in the CHARA/MIRC-X beam train adds instrumental polarization at the 15% level
- Can describe the path for each beam with a system of Jones matrices

$$\begin{pmatrix} E_H \\ E_V \end{pmatrix} = f \cdot e^{i\phi} \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{\alpha} \end{pmatrix} \mathbf{WP}(\zeta, \theta) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{8-19} \end{pmatrix} \mathbf{R}(A) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{4-7} \end{pmatrix} \mathbf{R}(a) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{1-3} \end{pmatrix} \mathbf{R}(q) \begin{pmatrix} E_\alpha \\ E_\delta \end{pmatrix}$$

$$\mathbf{WP}(\zeta, \theta) = \mathbf{R}(\theta) \begin{pmatrix} 1 & 0 \\ 0 & e^{i\zeta} \end{pmatrix} \mathbf{R}(-\theta)$$

Instrumental calibration

- Large AOI reflections in the CHARA/MIRC-X beam train adds instrumental polarization at the 15% level
- Can describe the path for each beam with a system of Jones matrices

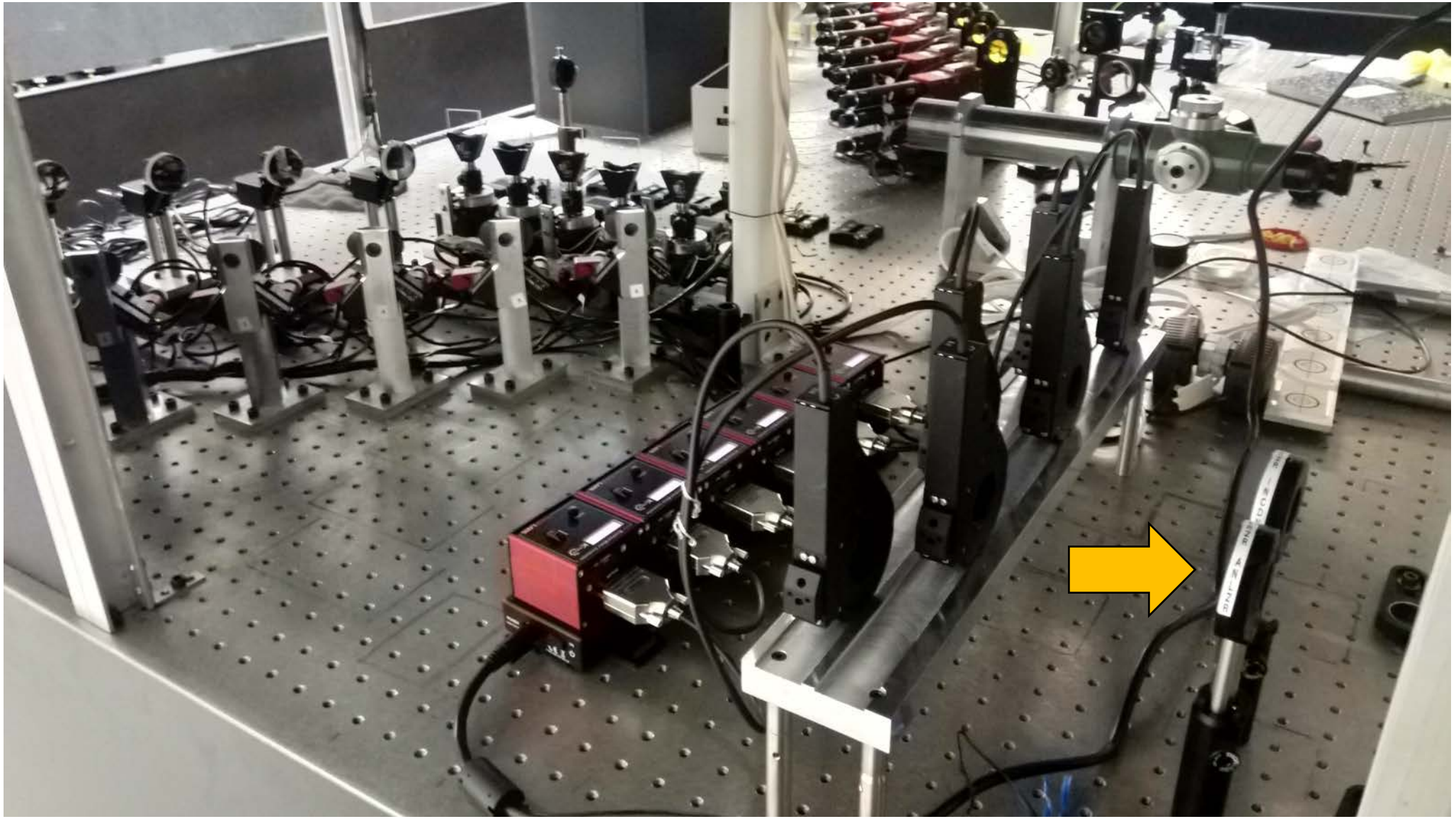
Azimuth Altitude Parallactic angle

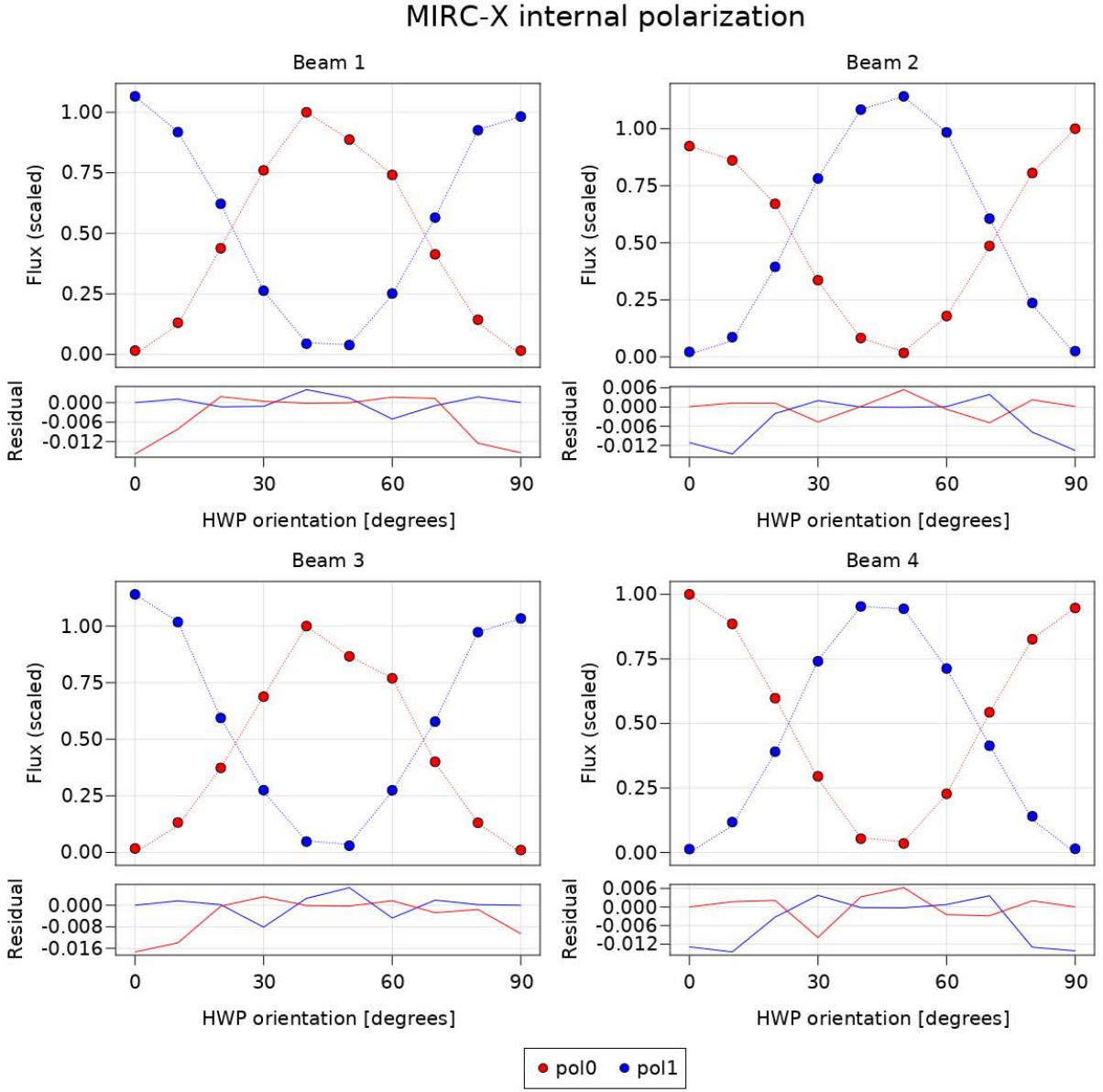
$$\begin{pmatrix} E_H \\ E_V \end{pmatrix} = f \cdot e^{i\phi} \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{\alpha} \end{pmatrix} \mathbf{WP}(\zeta,\theta) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{8-19} \end{pmatrix} \mathbf{R}(A) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{4-7} \end{pmatrix} \mathbf{R}(a) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{1-3} \end{pmatrix} \mathbf{R}(q) \begin{pmatrix} E_\alpha \\ E_\delta \end{pmatrix}$$

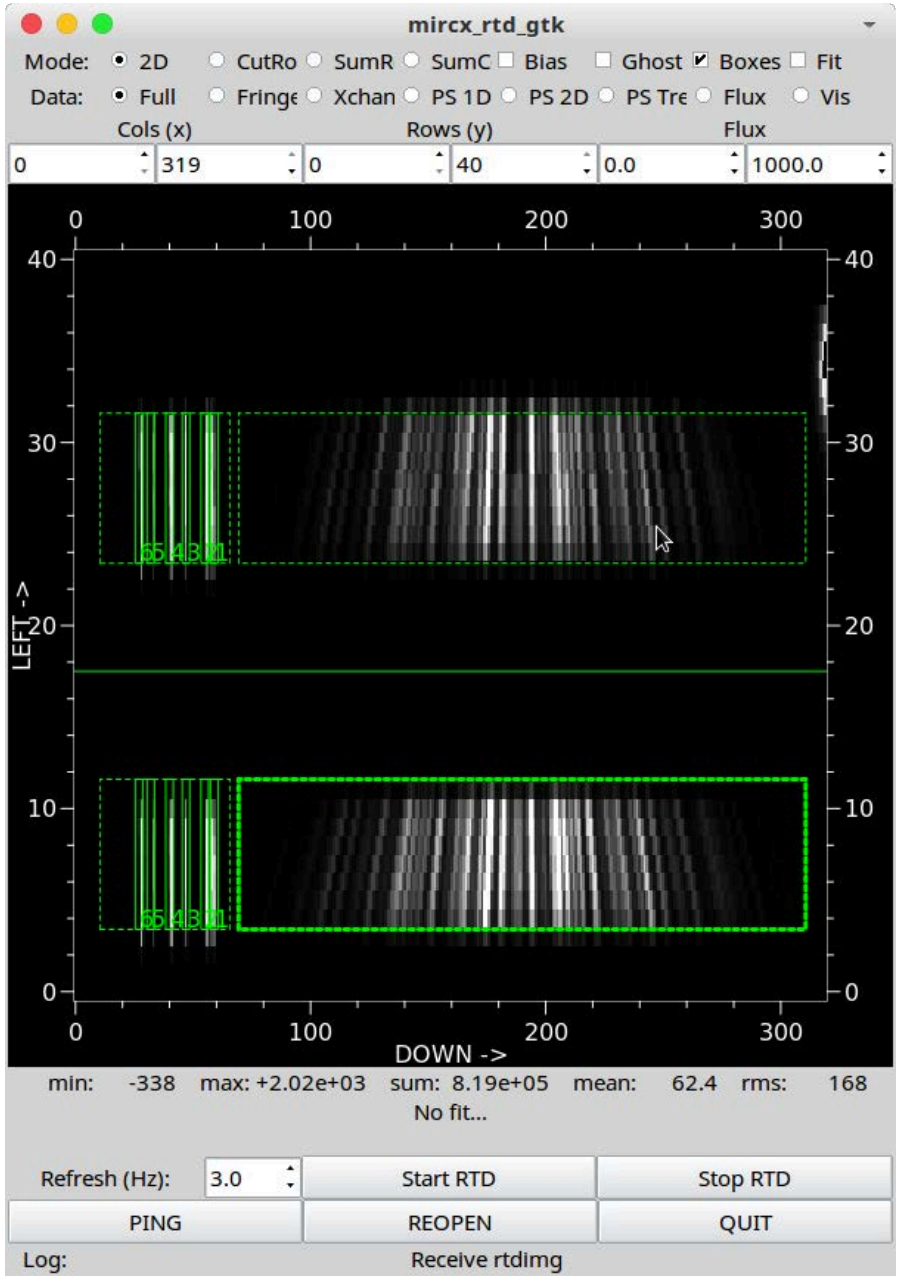
MIRC-X and HWP

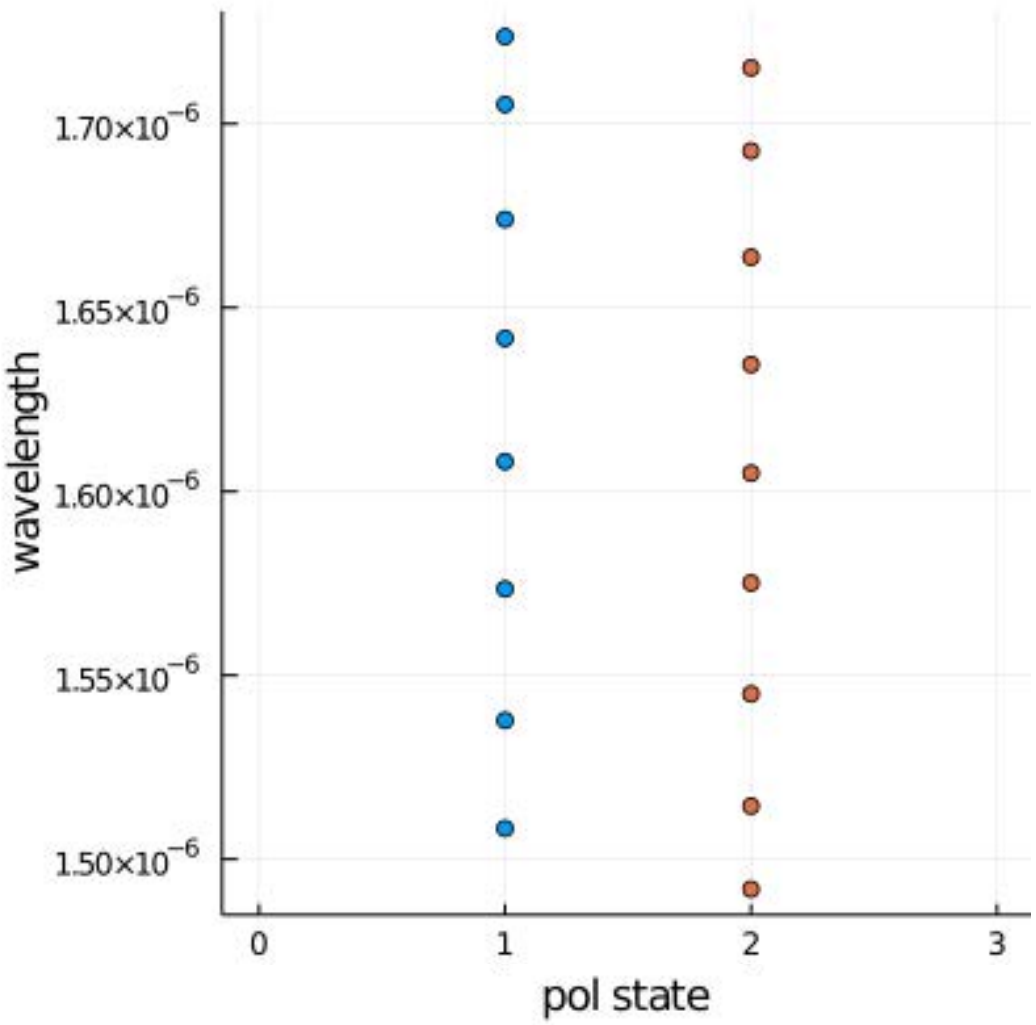
CHARA reflections

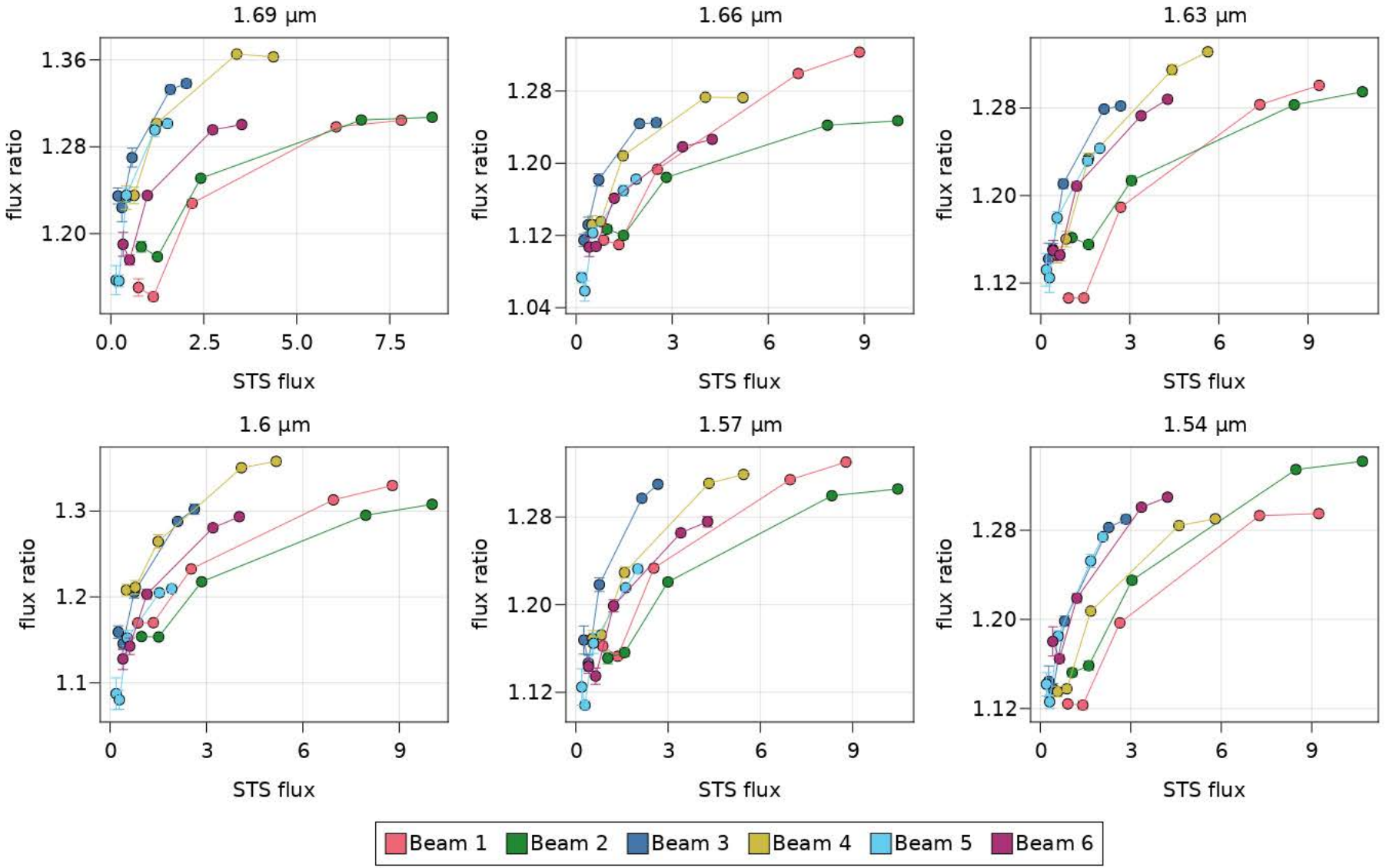
$$\mathbf{WP}(\zeta,\theta) = \mathbf{R}(\theta) \begin{pmatrix} 1 & 0 \\ 0 & e^{i\zeta} \end{pmatrix} \mathbf{R}(-\theta)$$




MIRC-X internal polarization
Beam 1
Beam 2
Beam 3
Beam 4
Flux (scaled)
Residual
HWP orientation [degrees]
pol0
pol1


mircx_rtd_gtk
Mode: 2D CutRo SumR SumC Bias Ghost Boxes Fit
Data: Full Fringe Xchan PS 1D PS 2D PS Tre Flux Vis
Cols (x)
Rows (y)
Flux
0
319
0
40
0.0
1000.0
LEFT ->
DOWN ->
min: -338 max: +2.02e+03 sum: 8.19e+05 mean: 62.4 rms: 168
No fit...
Refresh (Hz): 3.0
Start RTD
Stop RTD
PING
REOPEN
QUIT
Log:
Receive rtdimg


wavelength
1.70×10⁻⁶
1.65×10⁻⁶
1.60×10⁻⁶
1.55×10⁻⁶
1.50×10⁻⁶
pol state
0
1
2
3

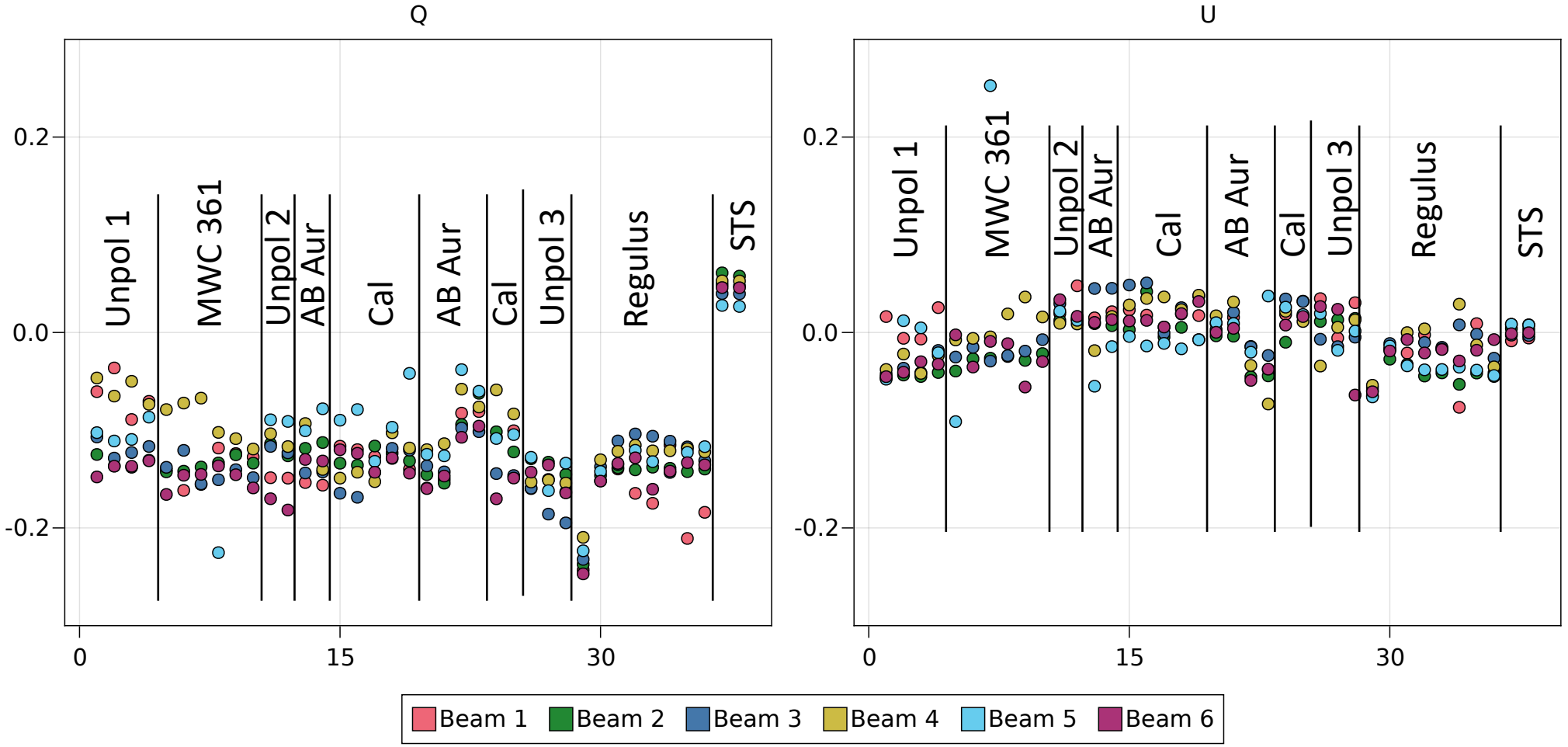

1.69 µm
1.66 µm
1.63 µm
1.6 µm
1.57 µm
1.54 µm
flux ratio
STS flux
Beam 1
Beam 2
Beam 3
Beam 4
Beam 5
Beam 6

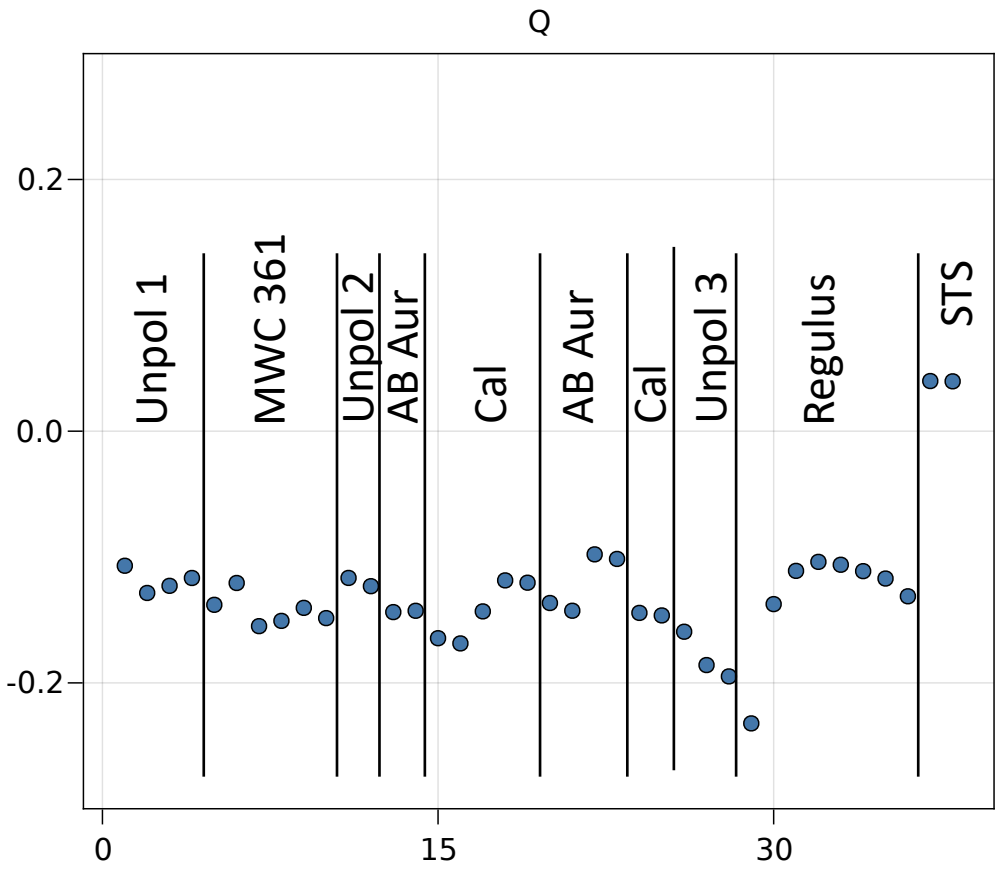
CHARA beam-path calibration

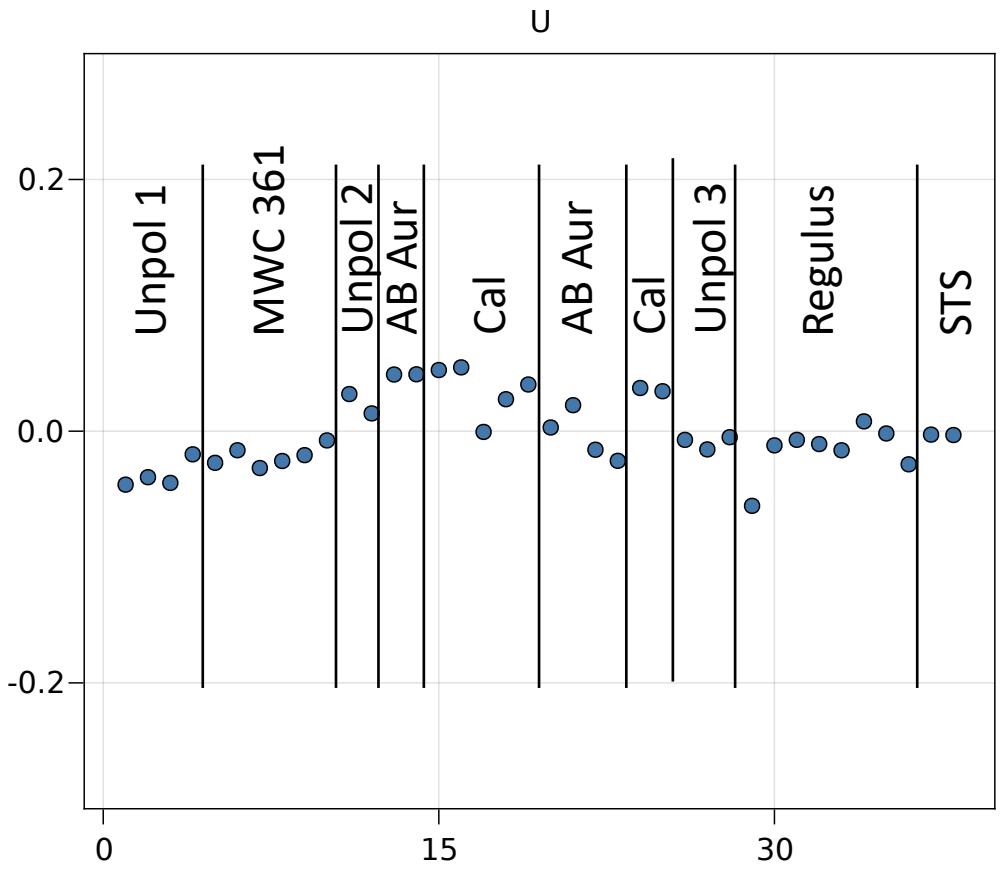
- We have observed a number of unpolarized targets in different regions of the sky
- Can extract Stokes Q and U before MIRC-X optics
- Fitting to CHARA parameters is still TODO

$$\begin{pmatrix} E_H \\ E_V \end{pmatrix} = f \cdot e^{i\phi} \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{\alpha} \end{pmatrix} \mathbf{WP}(\zeta,\theta) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{8-19} \end{pmatrix} \mathbf{R}(A) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{4-7} \end{pmatrix} \mathbf{R}(a) \begin{pmatrix} 1 & 0 \\ 0 & \widetilde{M}_{1-3} \end{pmatrix} \mathbf{R}(q) \begin{pmatrix} E_\alpha \\ E_\delta \end{pmatrix}$$

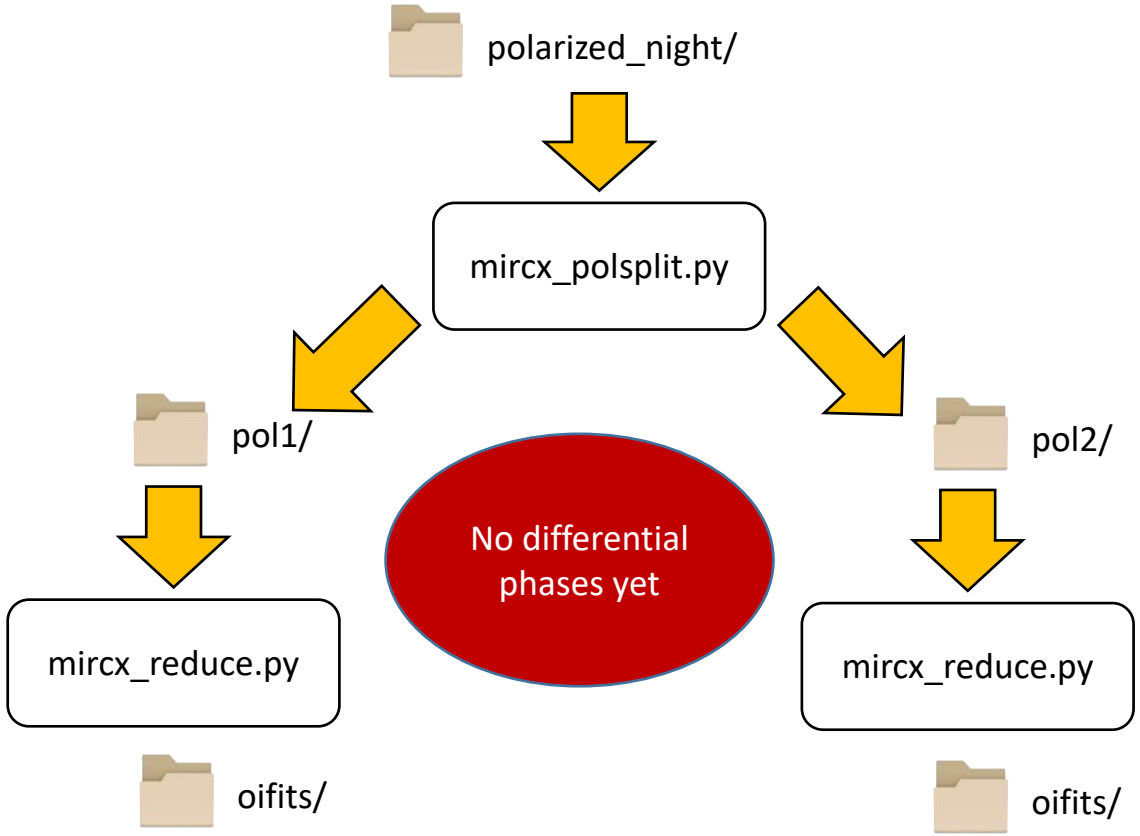
CHARA reflections


Q
U
0.2
0.0
-0.2
0
15
30
Unpol 1
MWC 361
Unpol 2
AB Aur
Cal
AB Aur
Cal
Unpol 3
Regulus
STS
Beam 1
Beam 2
Beam 3
Beam 4
Beam 5
Beam 6

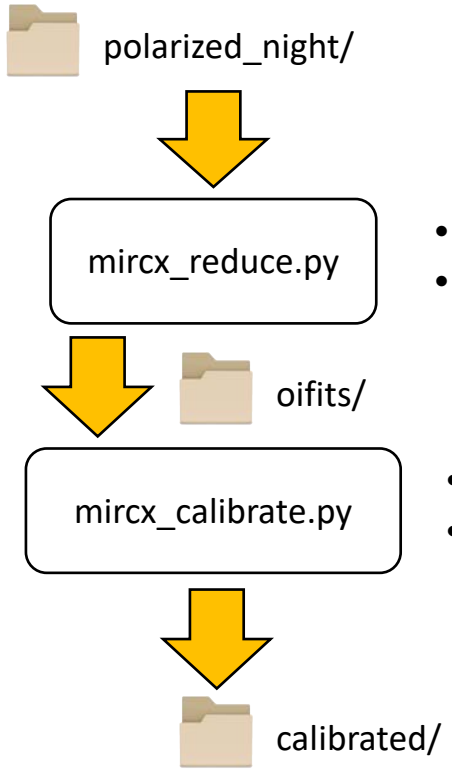

Q
0.2
0.0
-0.2
Unpol 1
MWC 361
Unpol 2
AB Aur
Cal
AB Aur
Cal
Unpol 3
Regulus
STS
0
15
30


U
0.2
0.0
-0.2
Unpol 1
MWC 361
Unpol 2
AB Aur
Cal
AB Aur
Cal
Unpol 3
Regulus
STS
0
15
30

Current Pipeline



Planned Pipeline



- Corrects instrumental polarization
- Reduces both polarizations simultaneously

- With differential visibility quantities
- Linear Stokes

Summary

- MIRC-X has a new R=50 polarization mode
  - First light with waveplates in 2019 November
  - New servers and GUI options tested in 2020 June and now part of regular suite
  - Commissioning of a motorized mount planned in Summer 2021 for on-demand use of this mode
- Ongoing work to understand instrumental polarization for calibration
- Data pipeline work coming