



MIRC-X instrument, performance and prospects



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MIRC-X science goals

- Imaging Young Stellar Objects
- Detecting exoplanets with high-precision astrometry
- Imaging stellar surfaces and starspots
- Faint binary detection
- Spectro-interferometry ($R_{\min}=22$, $R_{\max}=1176$)
- Polar-interferometry
- Simultaneous J+H + K-band (MYSTIC) observations

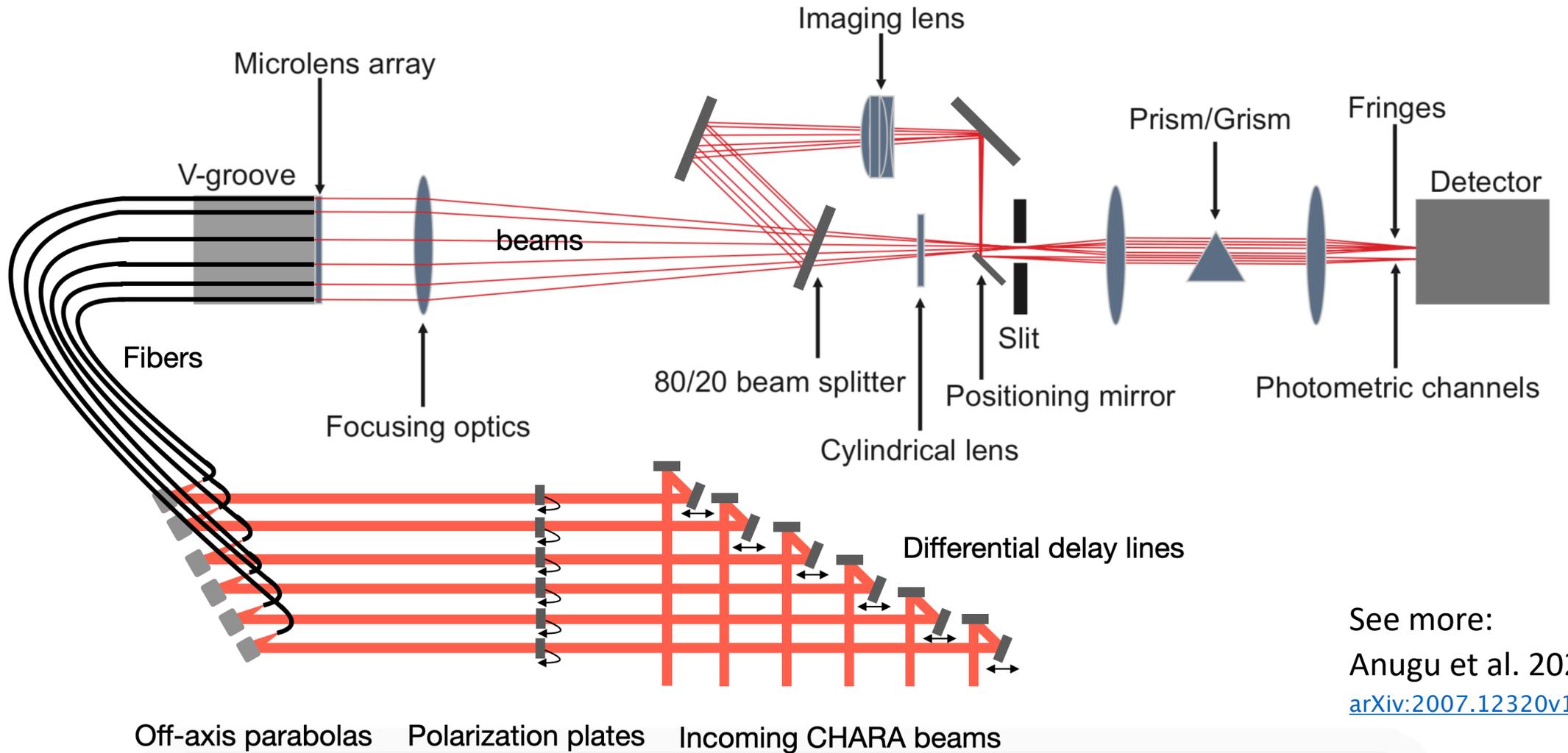
See more:

Anugu et al. 2020

[arXiv:2007.12320v1](https://arxiv.org/abs/2007.12320v1)

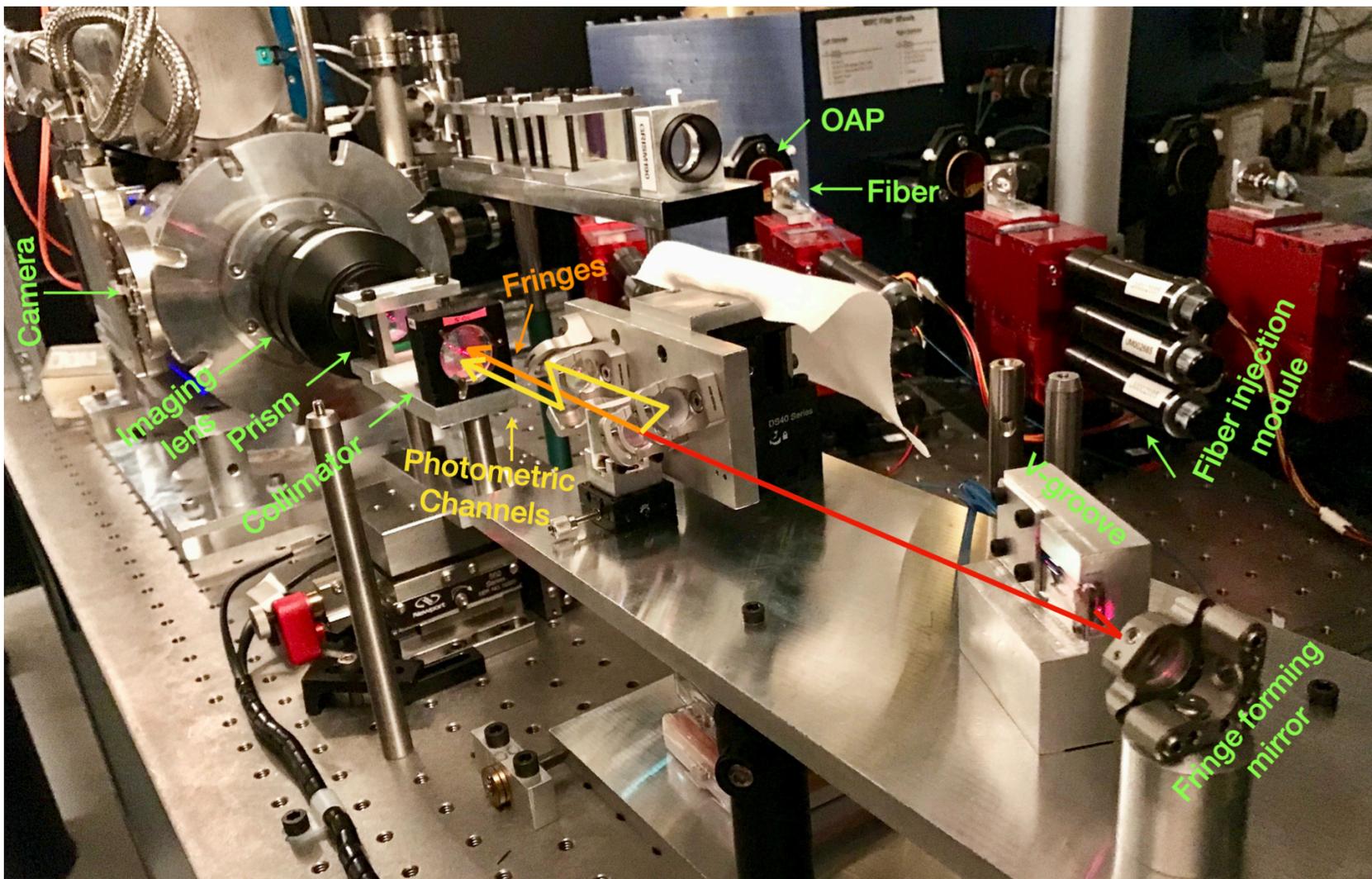


MIRC-X layout

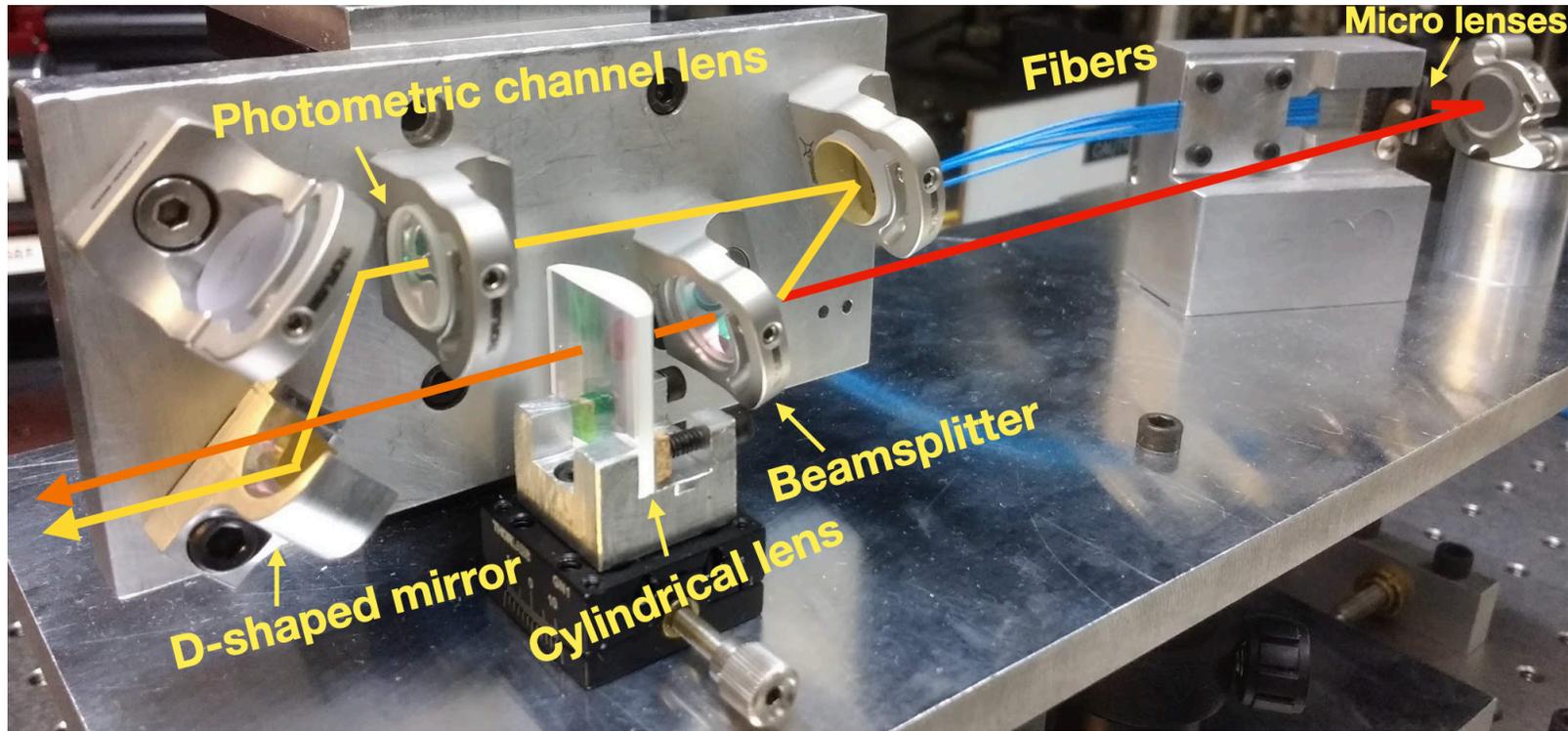


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MIRC-X as built

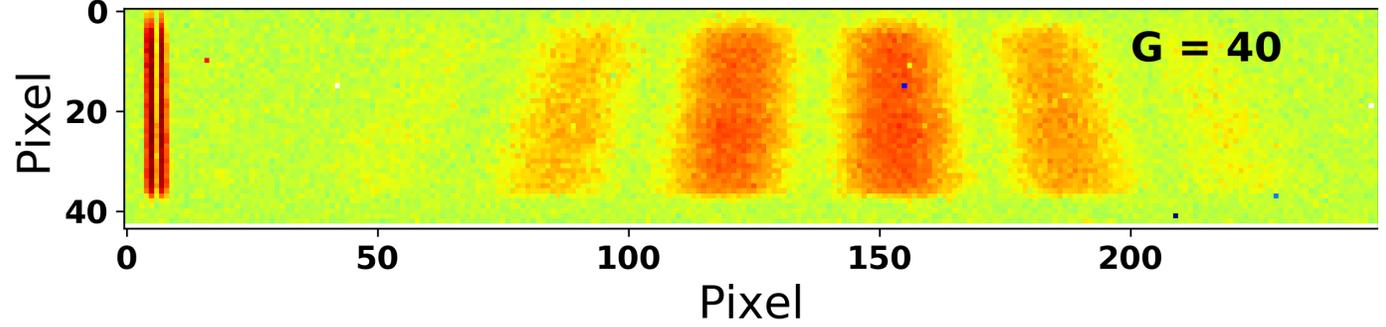
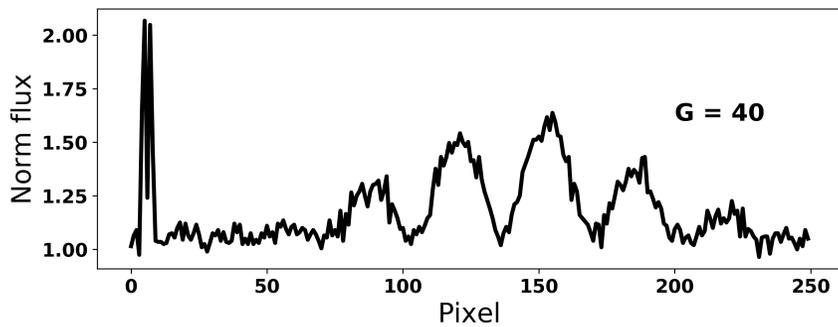
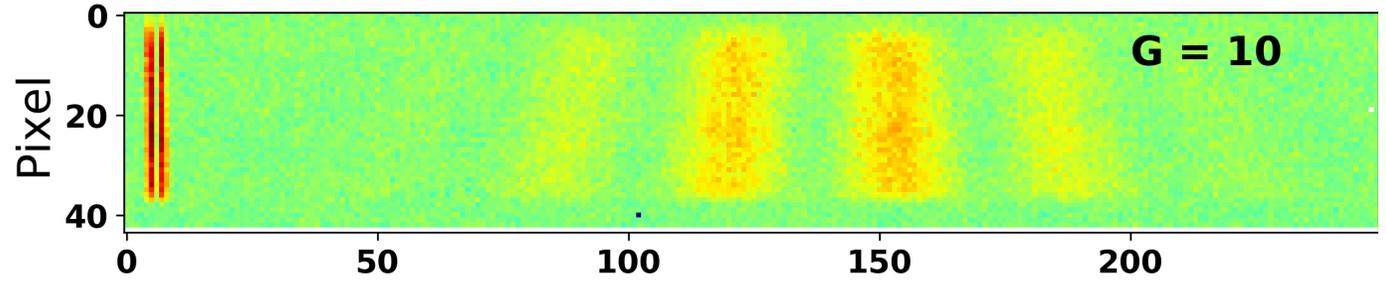
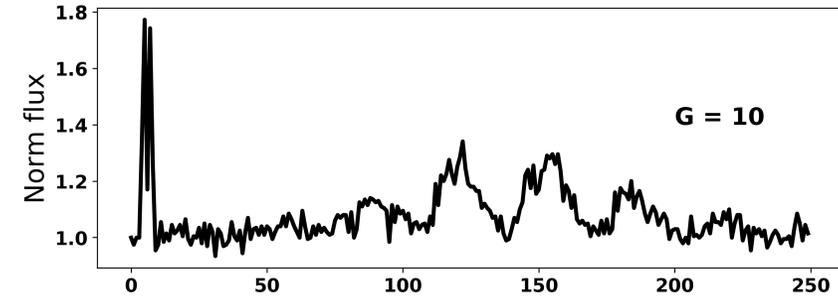
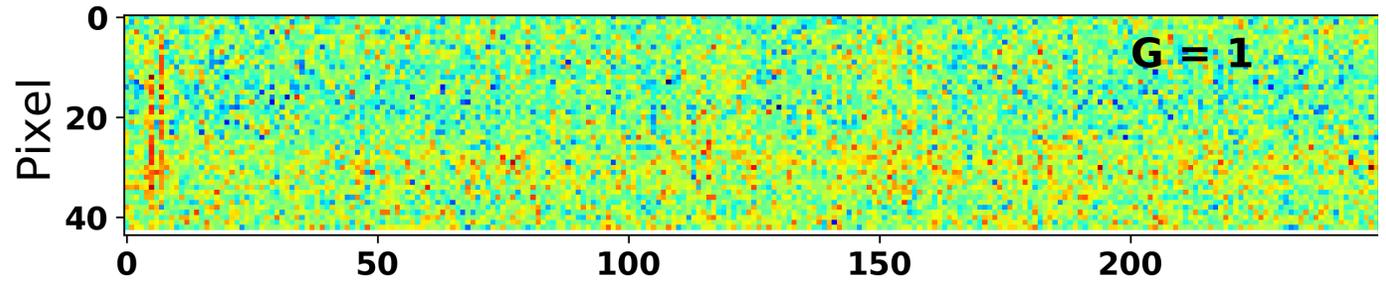
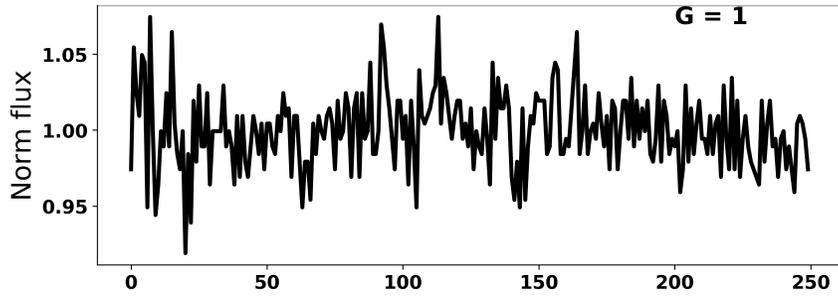


Highlight 1: Redesign of optics



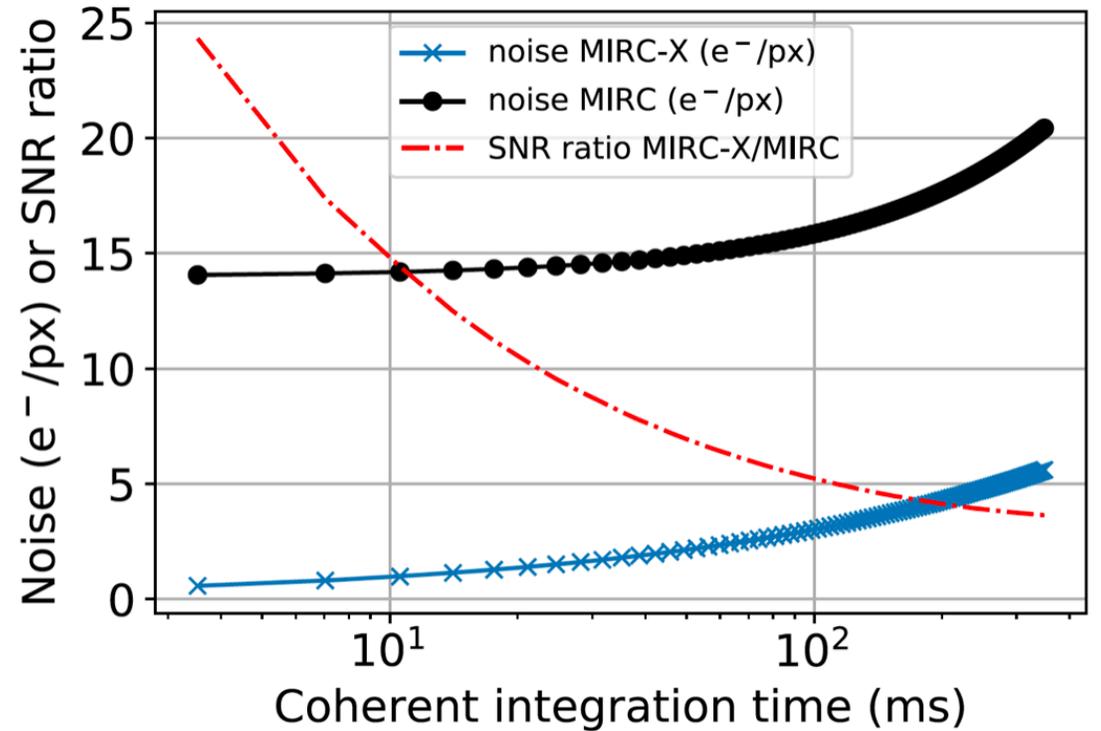
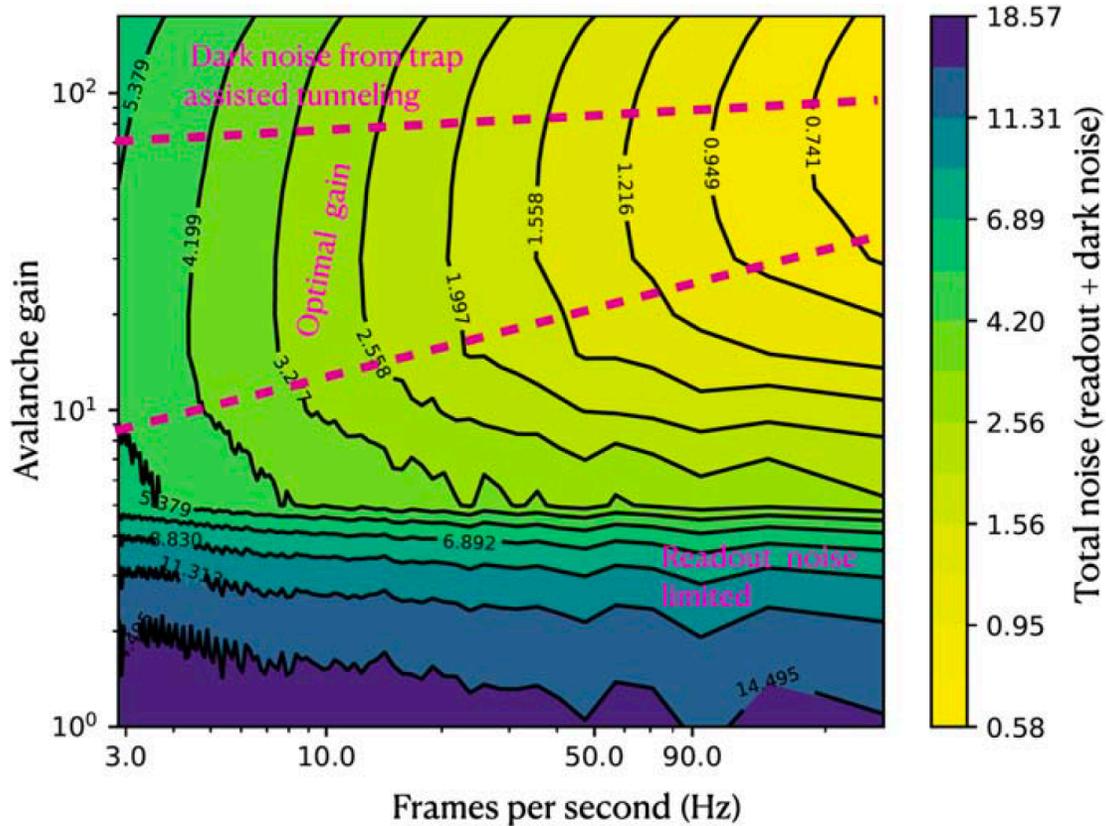
- Optimized for sensitivity
- Better photometer channels
- Less polarization
- Simple alignment
- Credit to J.B Le Bouquin

Highlight 2: Avalanche photodiode technology (C-RED ONE camera)





Highlight 2 : C-RED ONE performance



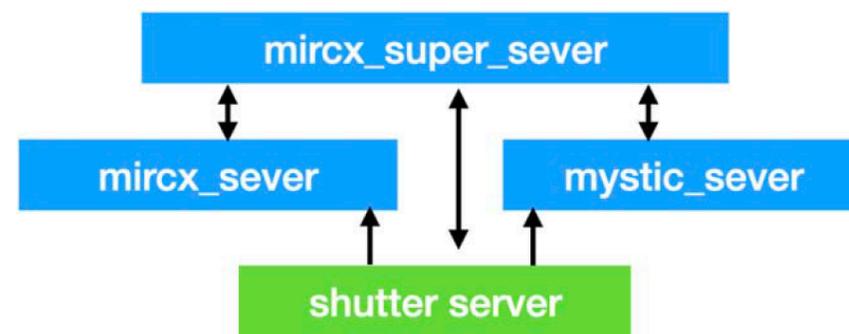
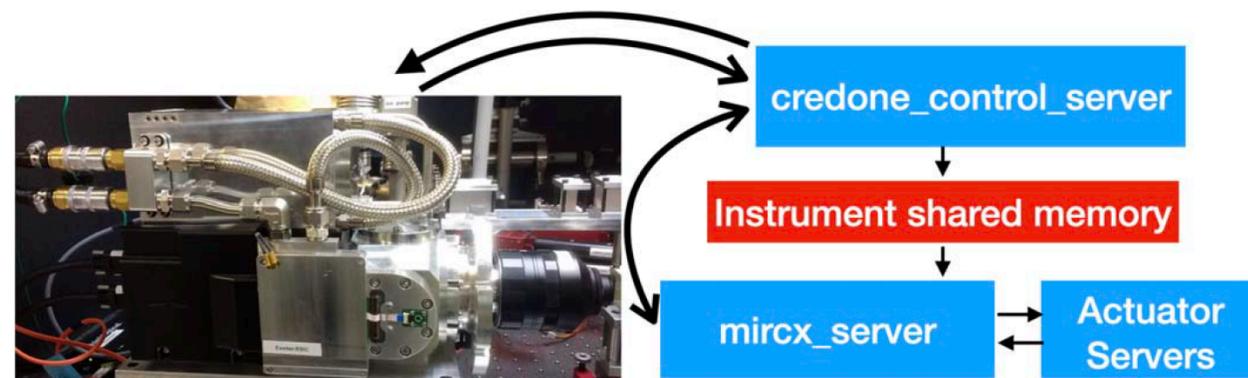
Anugu et al. 2020

[arXiv:2007.12320v1](https://arxiv.org/abs/2007.12320v1)

- Total transmission of 48% with QE + cold filters.
- IOTA readout mode (Nreads and Nloops)

Highlight 3 : Instrument and operational software

- CHARA standard and low-latency software
- Observing efficiency — high cadence observations
- Polarization Birefringence control
- Chromatic Dispersion Control
- Differential delay lines control
- Simultaneous observing with MYSTIC



Anugu et al. 2020

[arXiv:2007.12320v1](https://arxiv.org/abs/2007.12320v1)

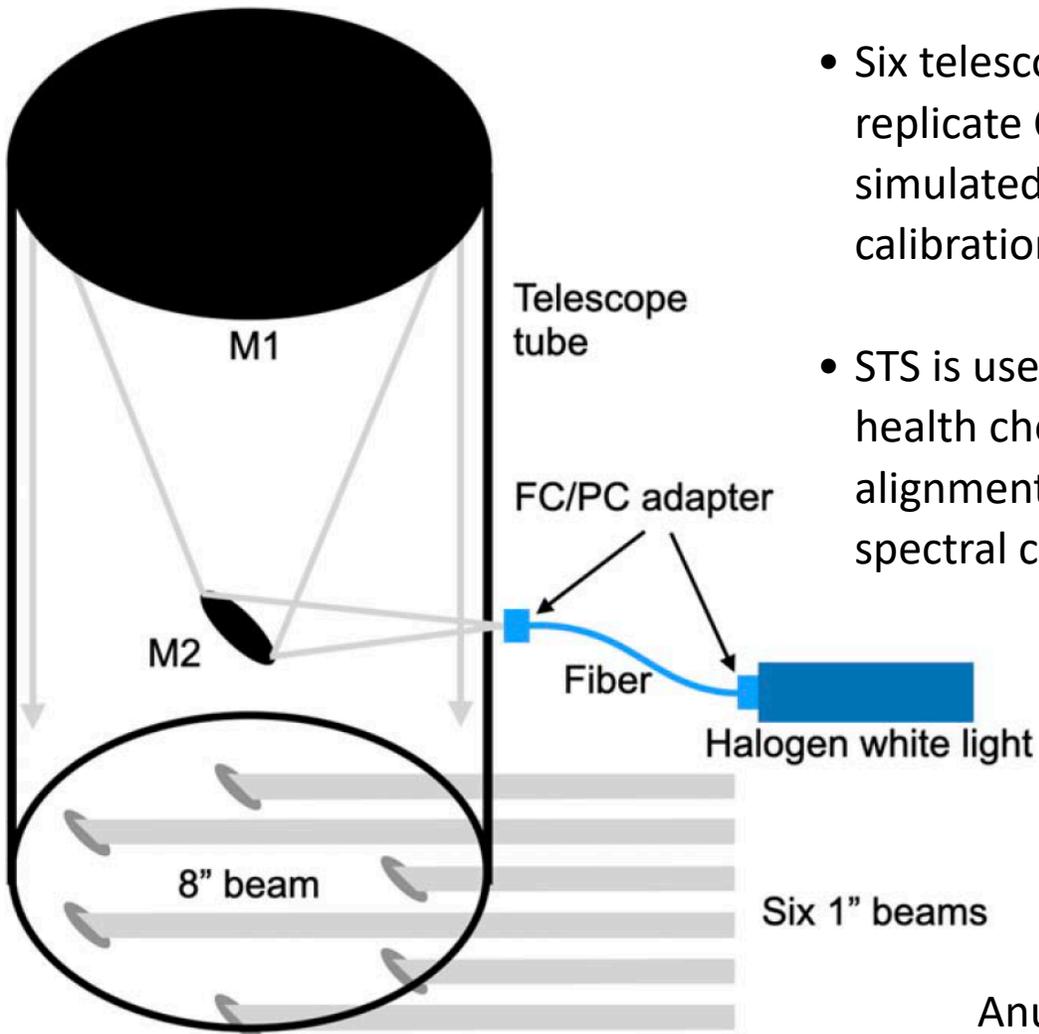


Highlight 3 : Instrument and operational software

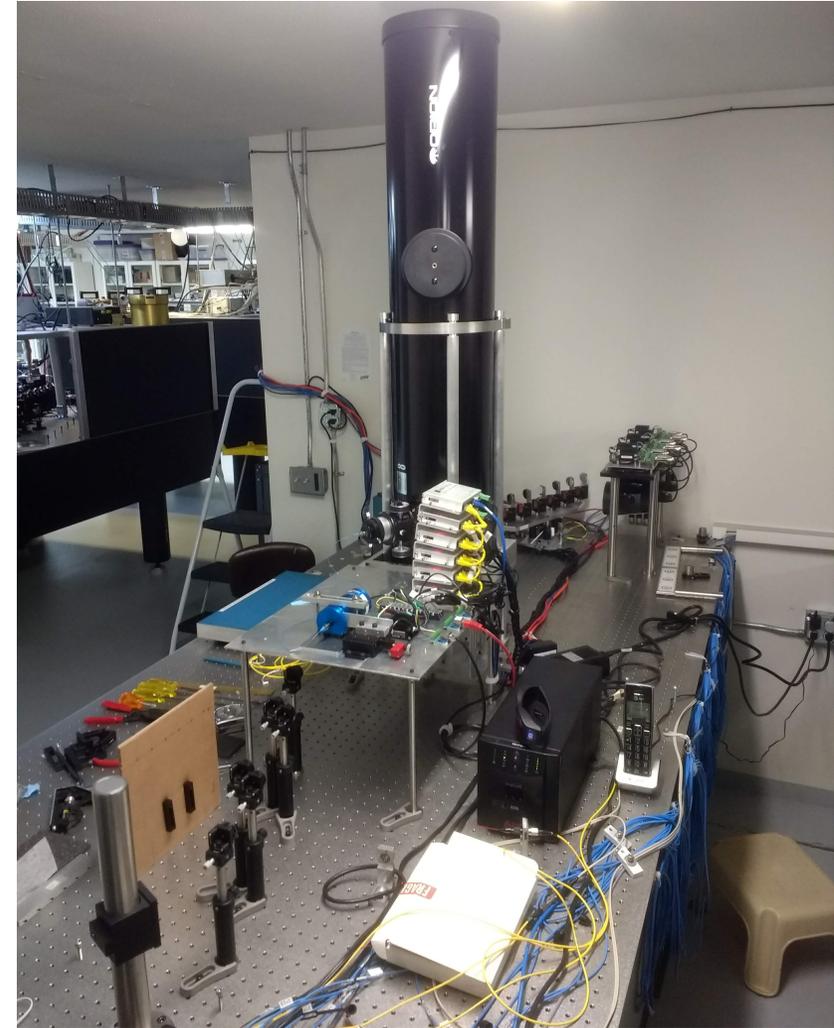
The screenshot displays a complex control room interface for the CHARA instrument. Key components include:

- mirrcx_server_gtk:** A window showing system parameters such as lambda (1.610000), bandwidth (-0.240000), and Cpeak (6.27426072). It includes a 'Parameters' table and a 'Servers status' section at the bottom.
- mirrcx_fiberexplorer_gtk:** A window with six fiber channel views (S1-S2, E1-E2, W1-W2) showing current x/y coordinates and flux values. It includes 'Xchan Map', 'Fringe Map', and 'Abort Map' buttons.
- mirrcx_gdt_gtk:** A window displaying a table of beam positions and control parameters. The table includes columns for beam ID, status, and various control parameters.
- Terminal - mirrcx_stepper_server:** A terminal window showing log messages such as 'MESSAGE: 1: Outlet -> 1'.
- Data Plots:** Two plots are visible: a line graph on the left showing flux vs. position with peaks labeled 1-12, and a 2D fringe map on the right showing a central bright spot with surrounding fringes.
- Control Panels:** Multiple windows with buttons for 'PING MIRCX', 'PING FIBER', 'REOPEN', 'QUIT', and 'Receive daq'.

Highlight 4 : Six Telescope Simulator (STS)



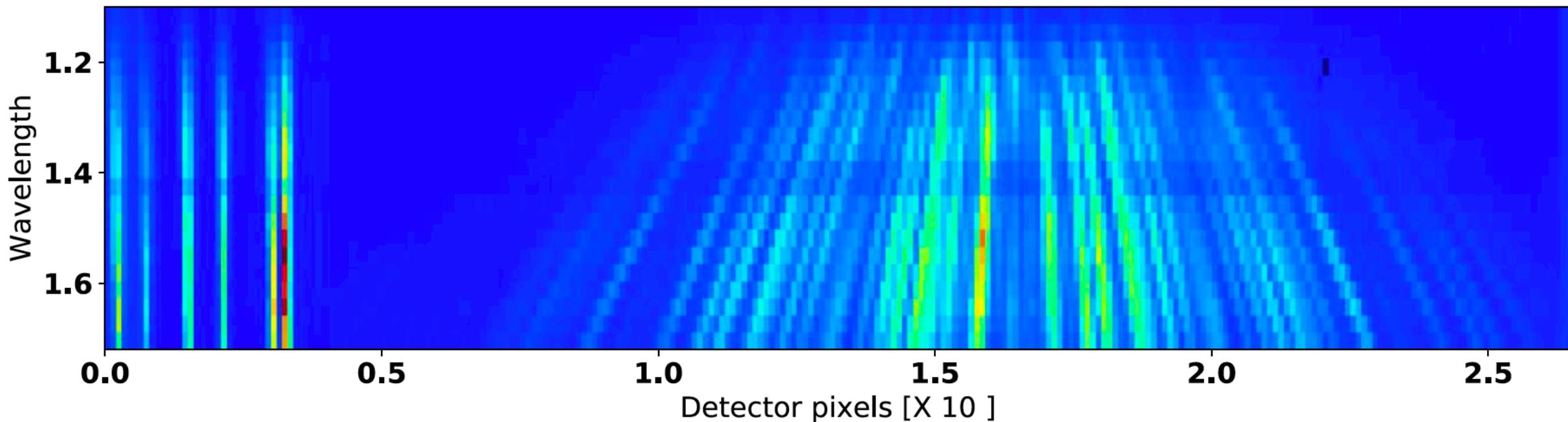
- Six telescopes which replicate CHARA are simulated for calibration
- STS is used for MIRC-X health checks, alignment, and spectral calibration.



Anugu et al. 2020
[arXiv:2007.12320v1](https://arxiv.org/abs/2007.12320v1)



Instrument mode 1 : J+H simultaneous observing (Currently experimental)



See Labdon et al. 2020 for science results on Fu Ori
[arXiv:2011.07865v1](https://arxiv.org/abs/2011.07865v1)



Instrument mode 2 : Spectro-interferometry

H-band

PRISM 22

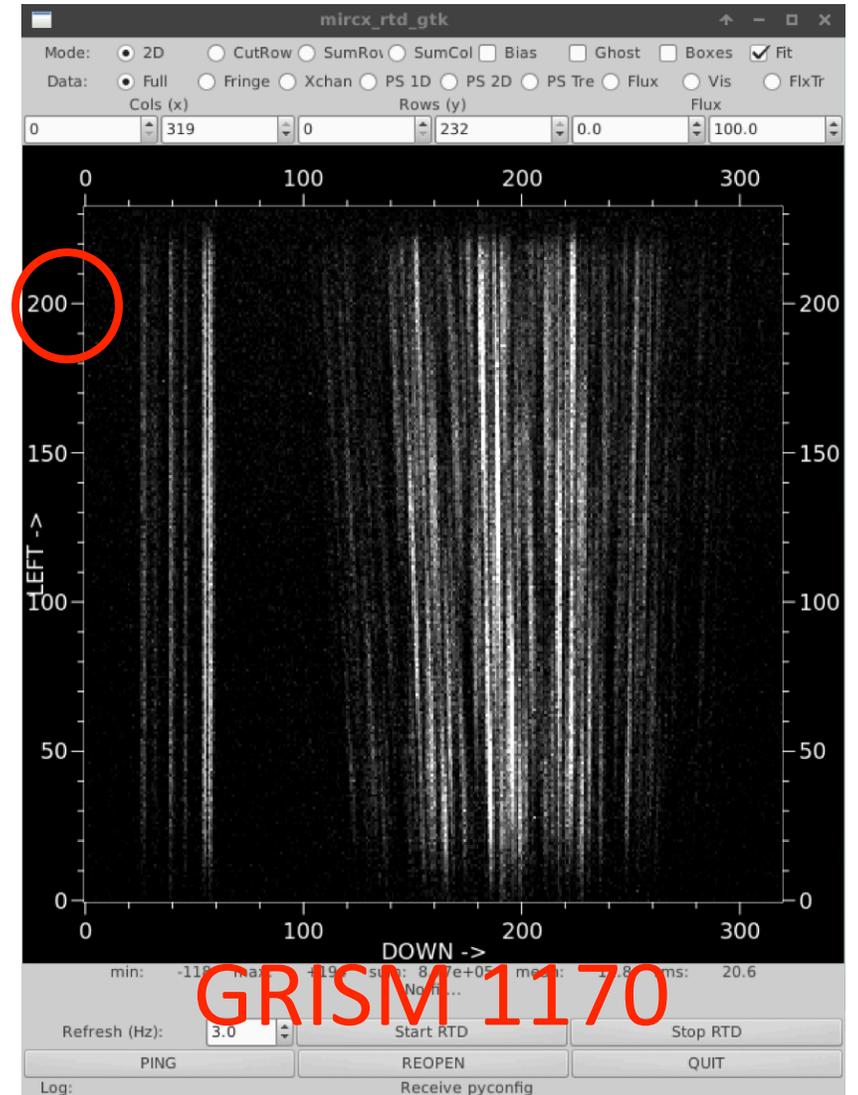
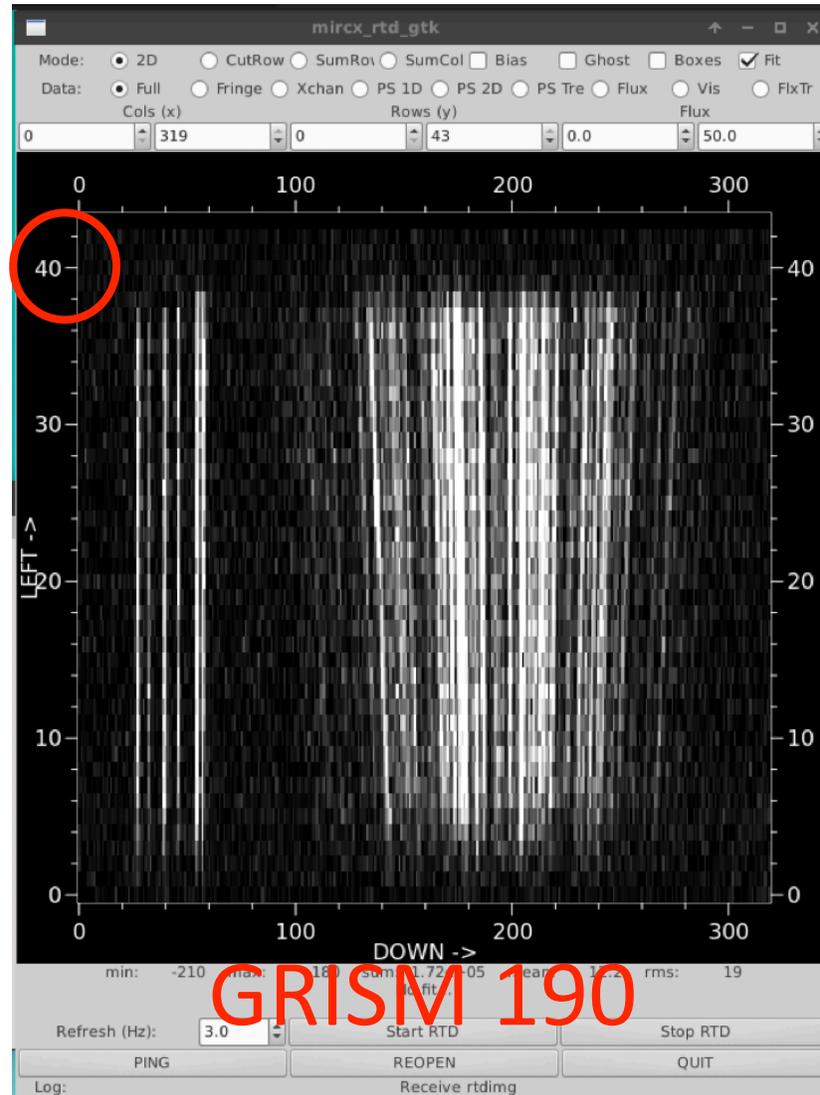
PRISM 50

GRISM 190

GRISM 1170

GRISM 1170

(experimental for now)



Instrument mode 3 : Polar-interferometry and polarization control

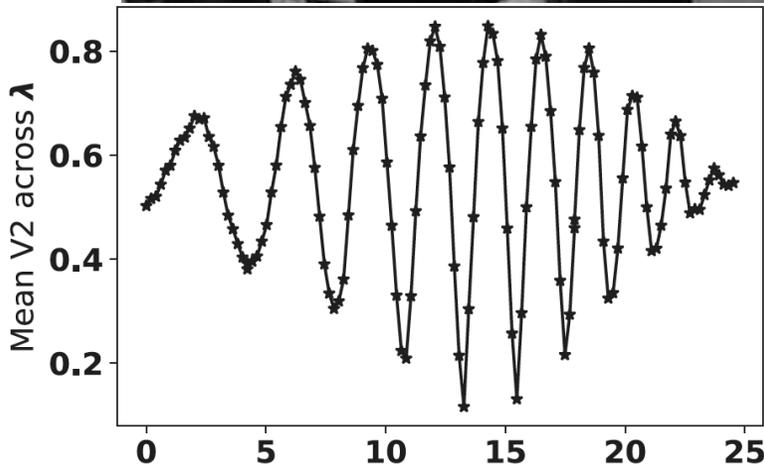
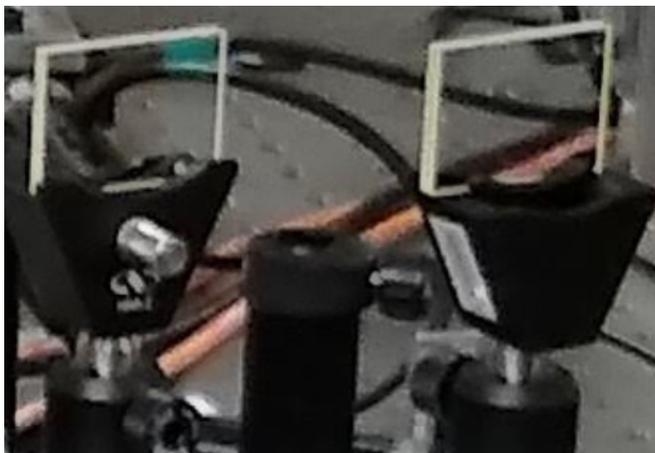


Plate angle (degree)

Anugu et al. 2020

[arXiv:2007.12320v1](https://arxiv.org/abs/2007.12320v1)

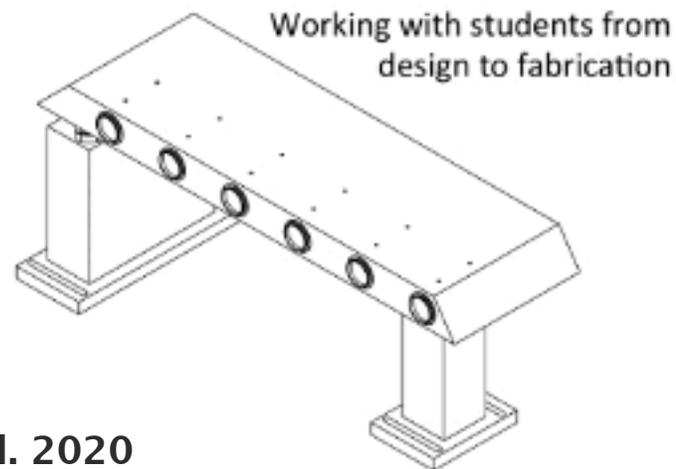
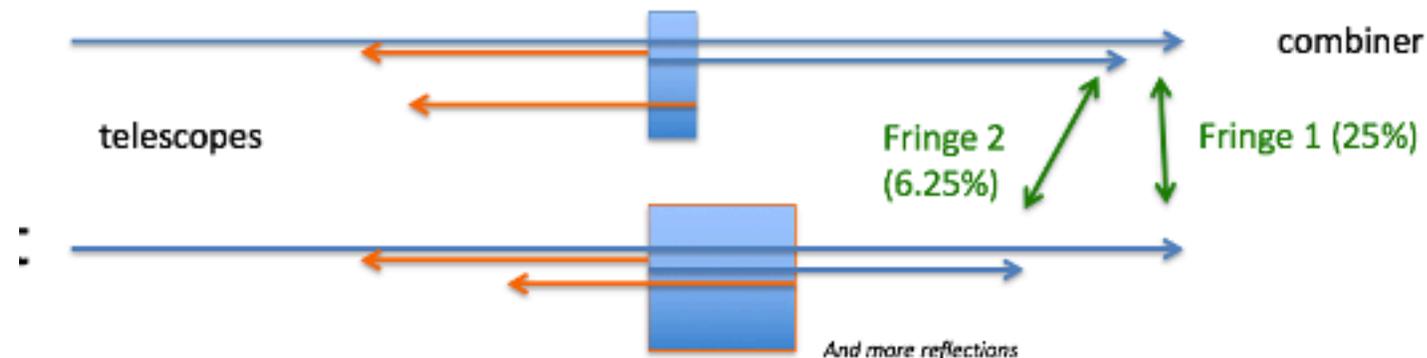
S1	S2	E1	E2	W1	W2
35.8	-	x	x	x	-2.40
7.1	9.7	-	x	x	-2.56
17.8	19.5	10.0	-	x	-1.34
52.0	84.0	26.6	41.9	-	-3.97
33.8	41.2	24.6	36.3	67.6	-

See Benjamin Setterholm talk

<https://doi.org/10.1117/12.2562407>

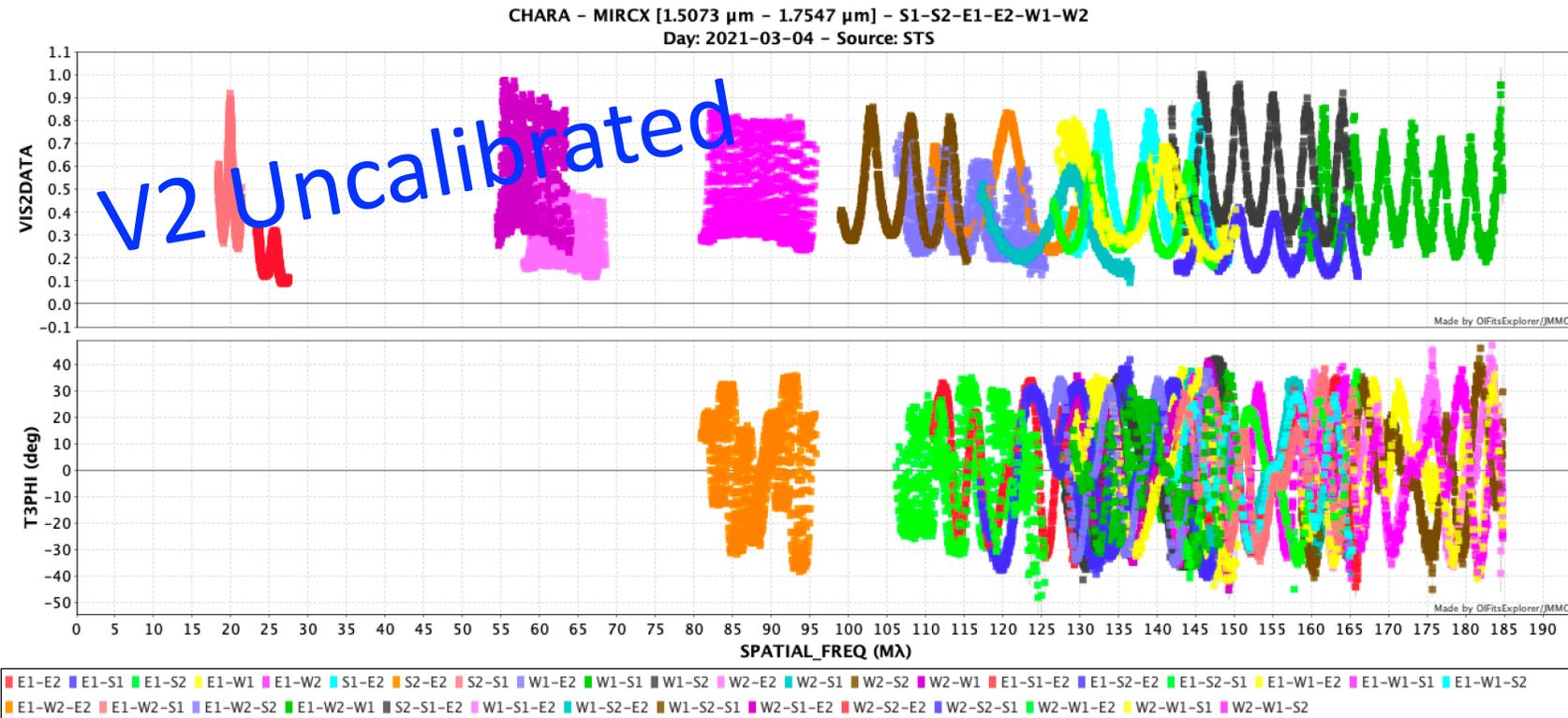
Instrument mode 4 : Etalon for wavelength calibration

- MIRC-X delivers 10 micro-arcseconds astrometry for close binaries
- For wider binaries (>100mas), we need precision and wavelength calibration, $\Delta\lambda/\lambda \sim 10^{-5}$
- Etalon mode is built for to do this precise wavelength calibration.



Gardner et al. 2020
[arXiv:2012.00778](https://arxiv.org/abs/2012.00778)

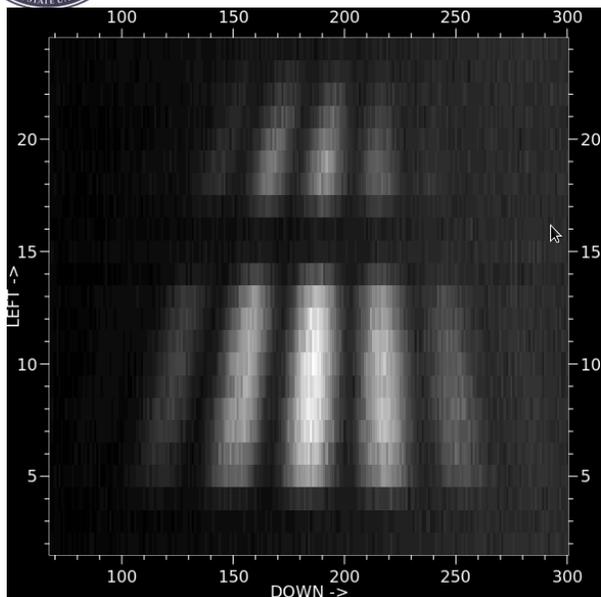
Instrument mode 4 : Etalon simulates a binary star



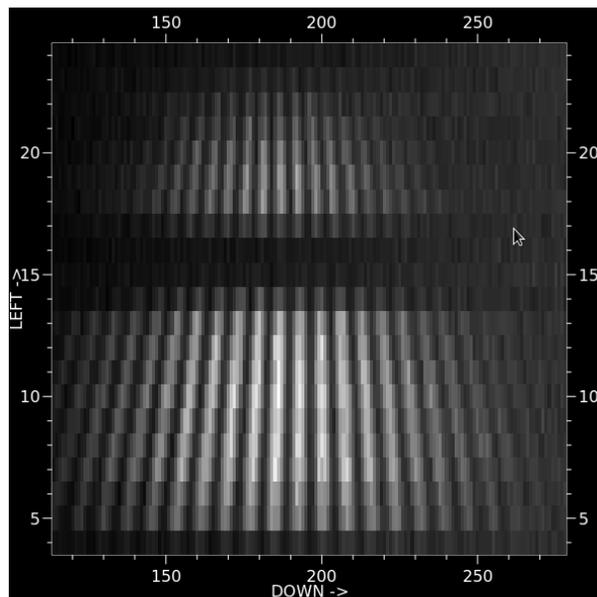
- Closure phases on this simulated binary is used to calibrate the wavelength.
- The wavelength calibration is internal to MIRC-X, so we use the Six Telescope Simulator lab light without extra on-sky time.

Gardner et al. 2020
[arXiv:2012.00778](https://arxiv.org/abs/2012.00778)

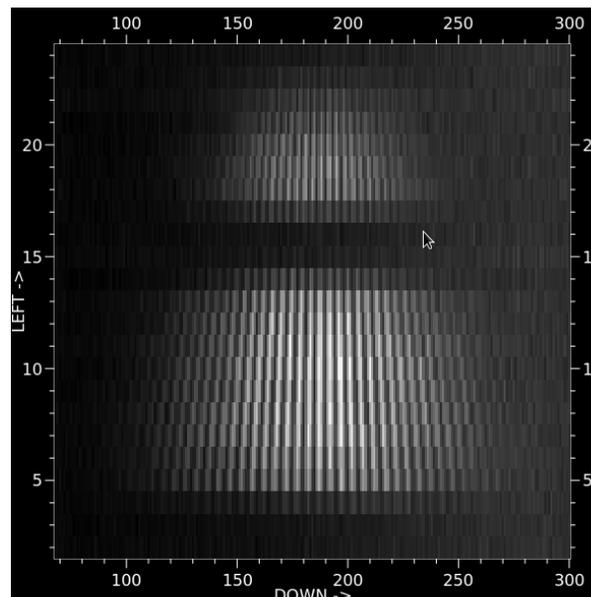
Performance : contrast of fringes



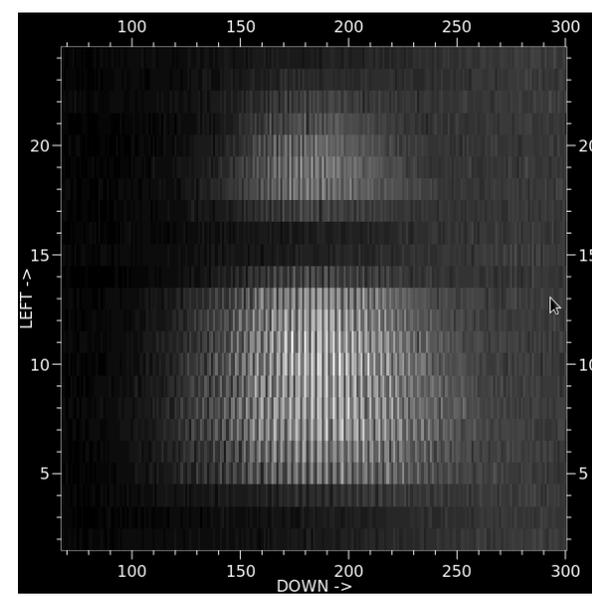
Beams: 1+2



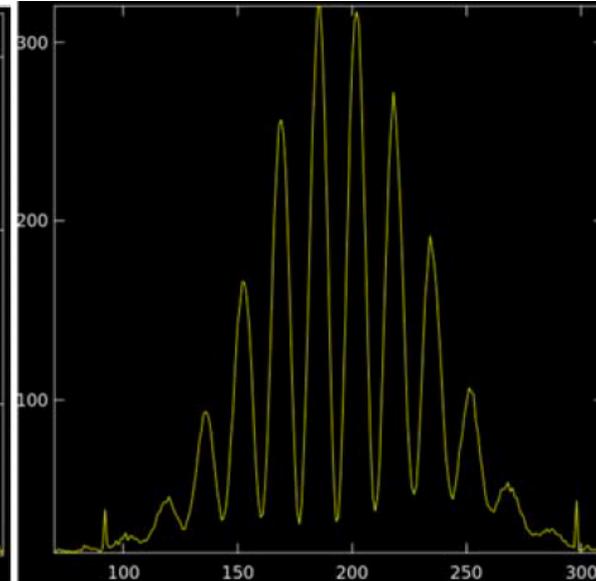
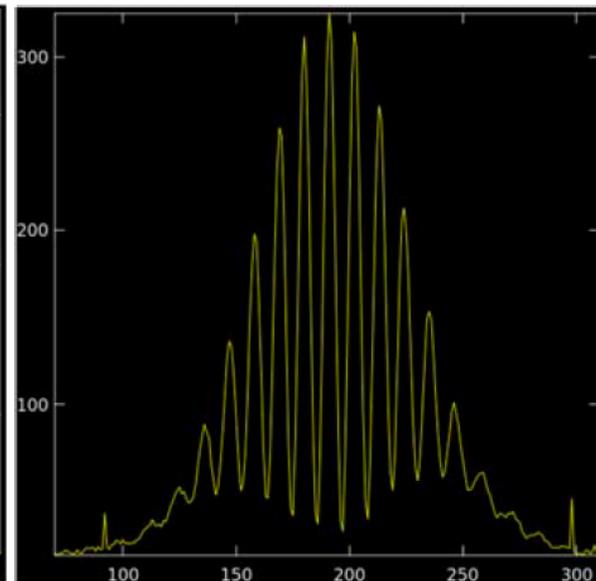
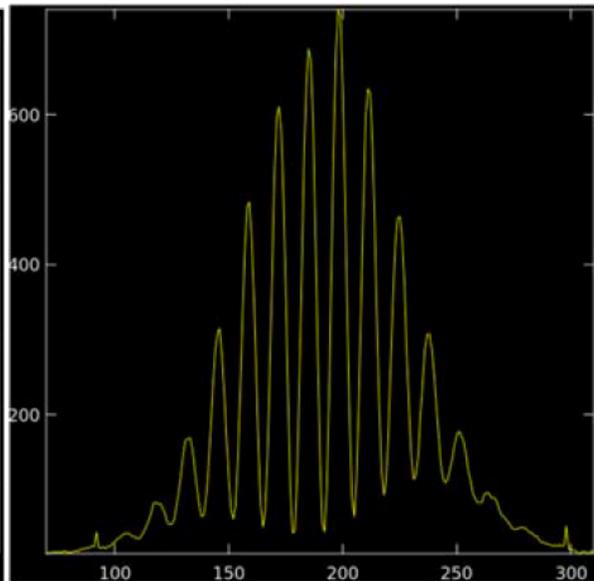
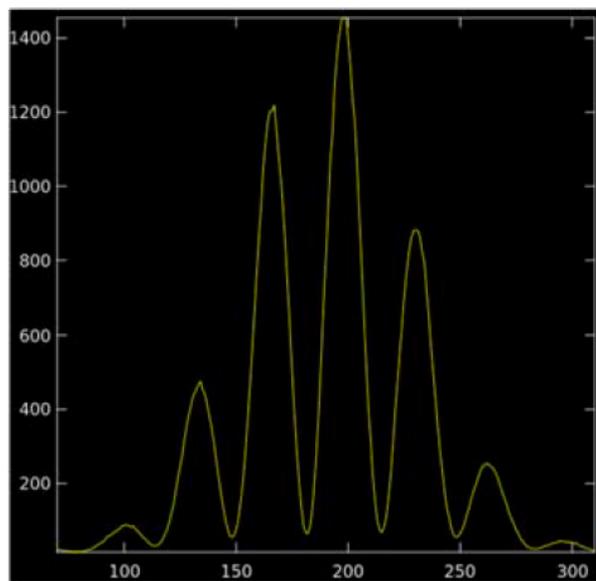
Beams: 1+3



Beams: 1+4



Beams: 1+6

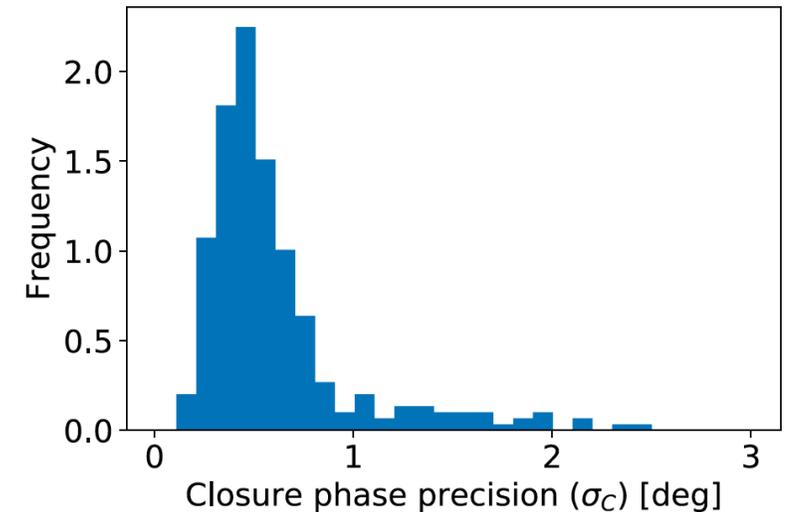
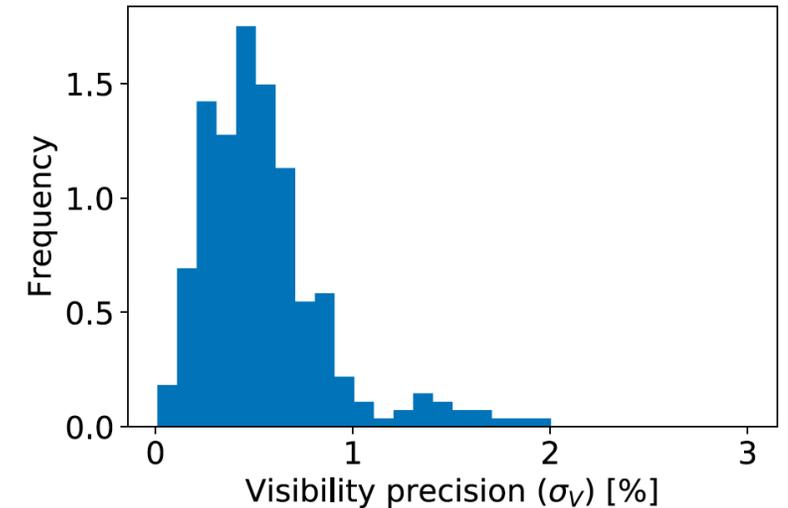


Performance: Visibility and closure phase precision

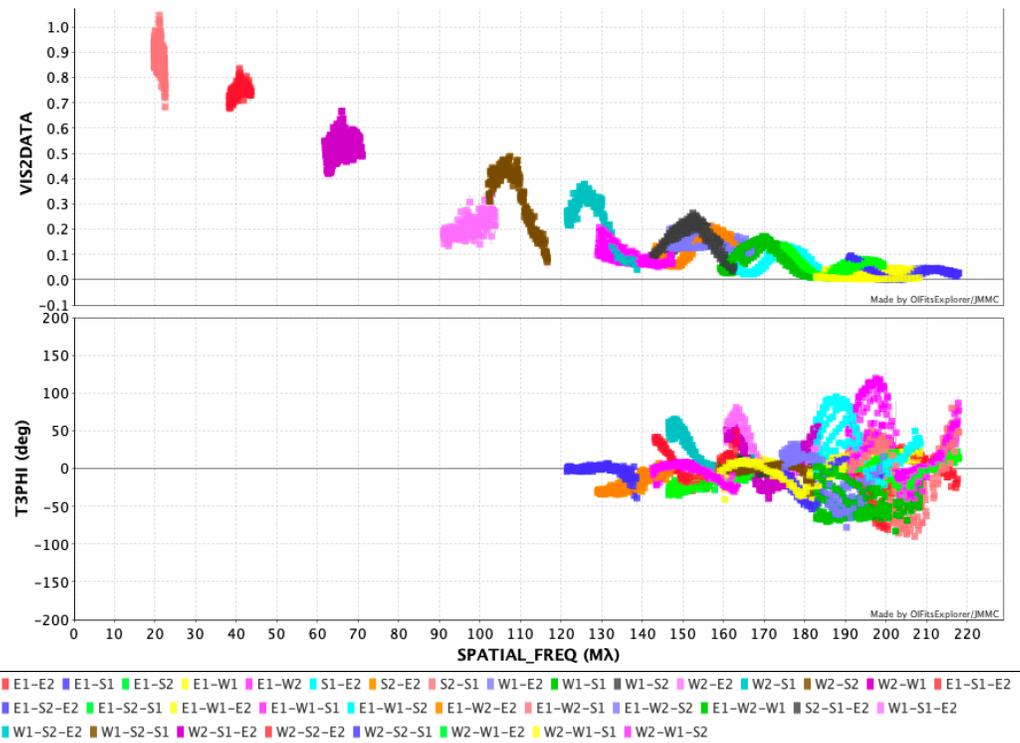
- Pipeline is written in Python (led by J. B. Le Bouquin)
- Mostly automatic (if the data is good)
- John Monnier's MIRC IDL scripts to play with data filtering

Visibility precision better than 1%,
and closure phase precision better than 1°
for good nights.

See more:
Anugu et al. 2020
[arXiv:2007.12320v1](https://arxiv.org/abs/2007.12320v1)

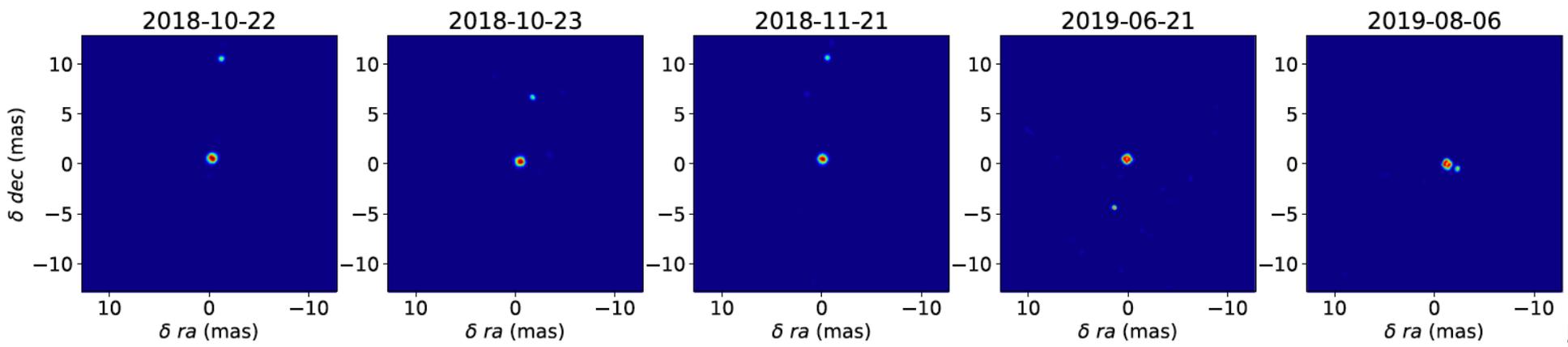
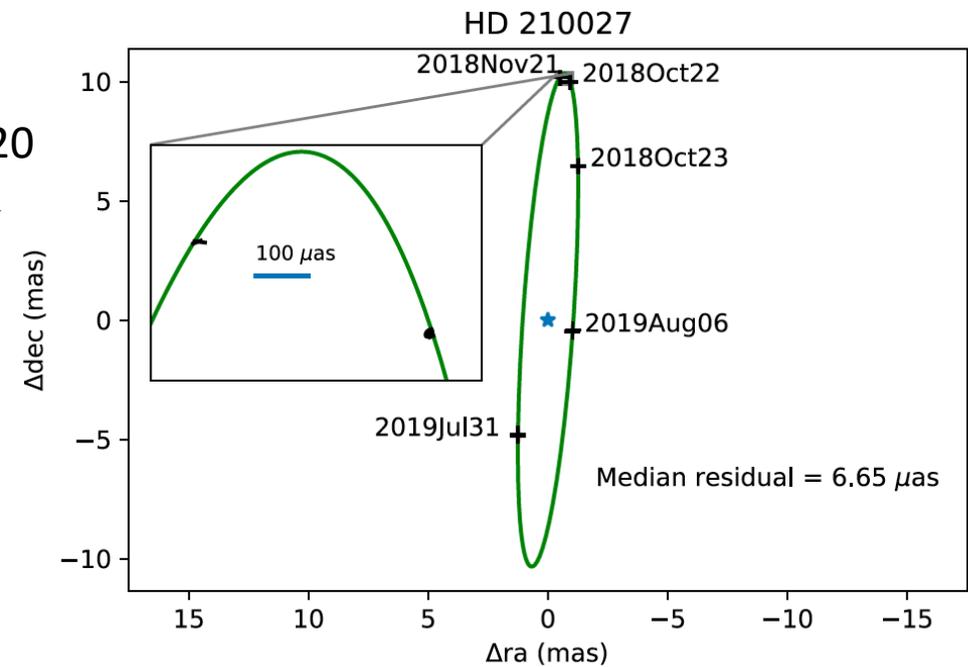


An example astrophysical result: Iota Peg



Anugu et al. 2020
[arXiv:2007.12320v1](https://arxiv.org/abs/2007.12320v1)

Orbital astrometry ~7micro-arcseconds precision.



Summary

- So far we are satisfied with the performance
- Sensitivity improved by **2 magnitudes**
- Several instrument modes (R=22, 50, 190, 1170; J+H bands, polar-interferometry)
- Delivered 7 papers so far ([Chiavassa et al. 2020](#), [Kraus et al. 2020](#), [Anugu et al. 2020](#), [Labdon et al. 2020](#), [Gardner et al. 2020](#), [Richardson et al. 2021](#), [Thomas et al. in revision](#))
- MIRC-X has been the mostly requested instrument at CHARA since installation (VEGA, CLASSIC moving towards upgrades)



Prospects

- We have $<0.7\text{mm}$ equalized fibers in hand to minimize birefringence and the new v-groove will be installed. Should help J+H-band observations.
- Filter-wheel installation
- Simultaneous operation with future MYSTIC and SPICA
- Accelerometer installation to measure vibrations (hopefully real-time corrections)
- Pipeline improvements