



The installation and commissioning of

MATISSE



The new VLT mid-infrared instrument

Anthony Meilland

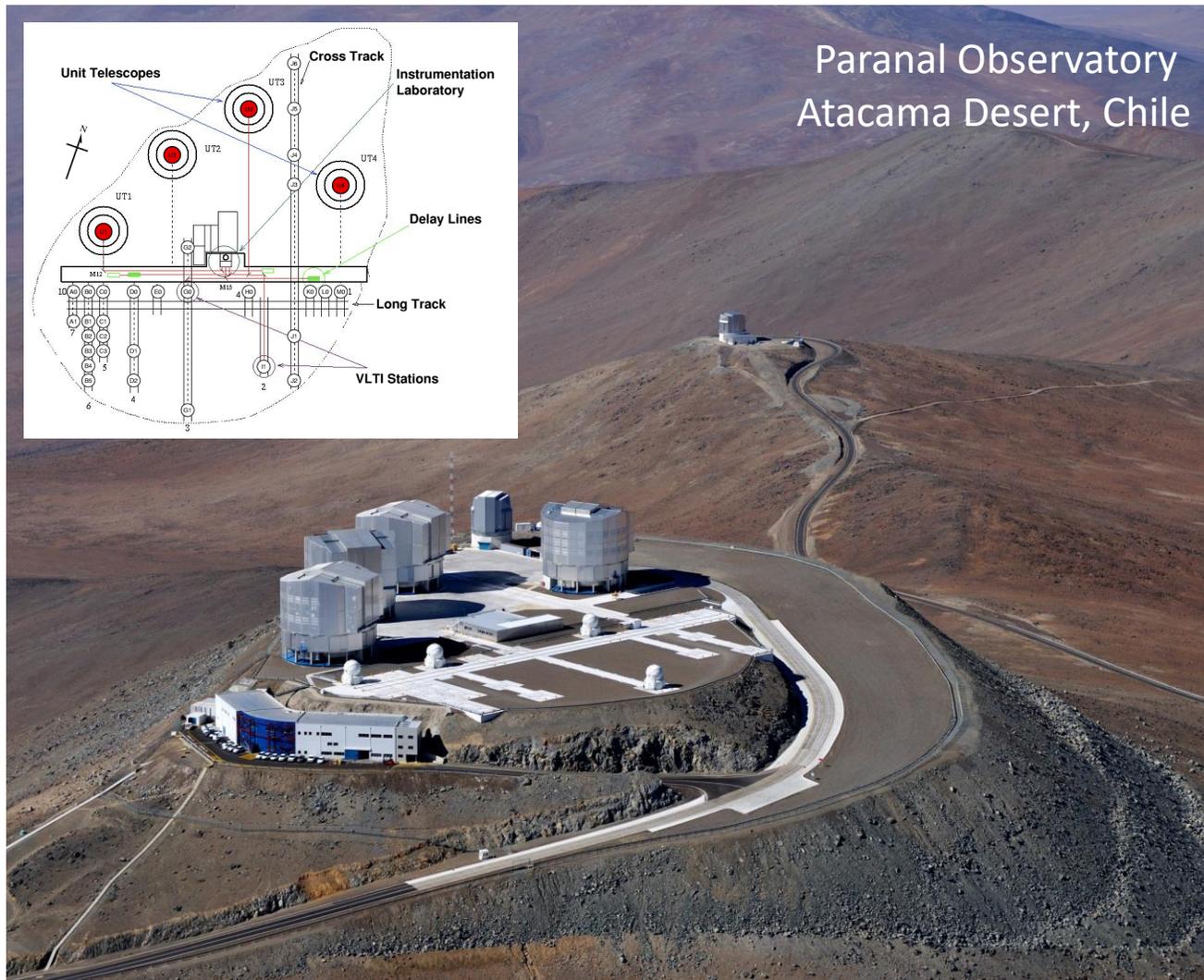
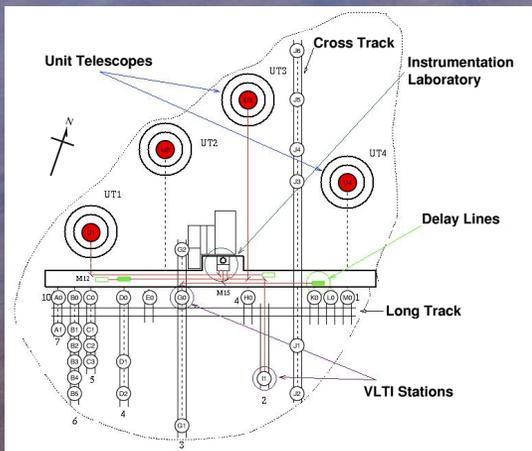
And the MATISSE commissioning team

Bruno Lopez, Stephane Lagarde, Romain Petrov, Philippe B erio, Florentin Millour, Pierre Cruzalebes, Sylvie Robbes, Fatm e Allouche, Alexis Matter...

Current Status of VLTI



Paranal Observatory Atacama Desert, Chile



4 Unit Telescopes (8.2m)

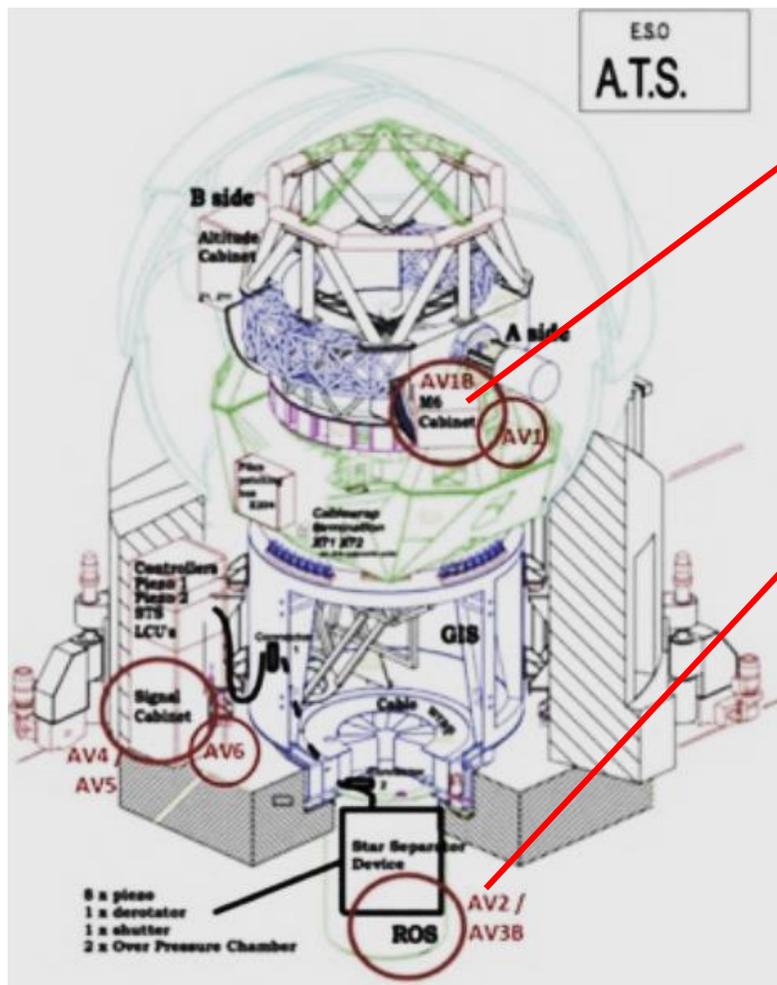
- Fixed : B = 46 – 130 m
- Equipped with 60 actuators AO (MACAO)
- Two wavefront sensors:
 - Visible : MACAO
 - Near-IR : CIAO (developed for GRAVITY)

4 Auxiliary Telescopes (1.8m)

- Movable : B = 13 – 140 m
- Recently equipped with a AO (NAOMI)

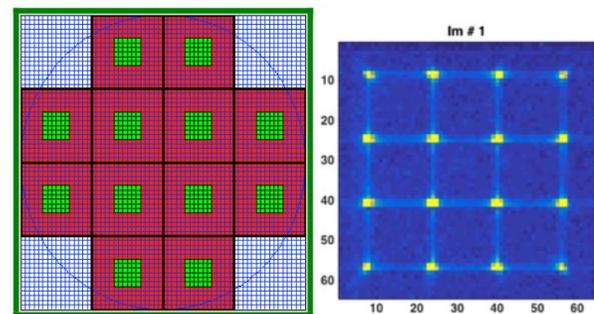


Current Status of VLTI NAOMI



Deformable Mirror
ALPAO DM241

Wavefront Sensor
4x4 Shack-Hartmann



Installed in September 2018
Commissioned in fall 2018

Improve the limiting magnitude (1mag)
Faster object acquisition (<2min)

Current Status of VLTI



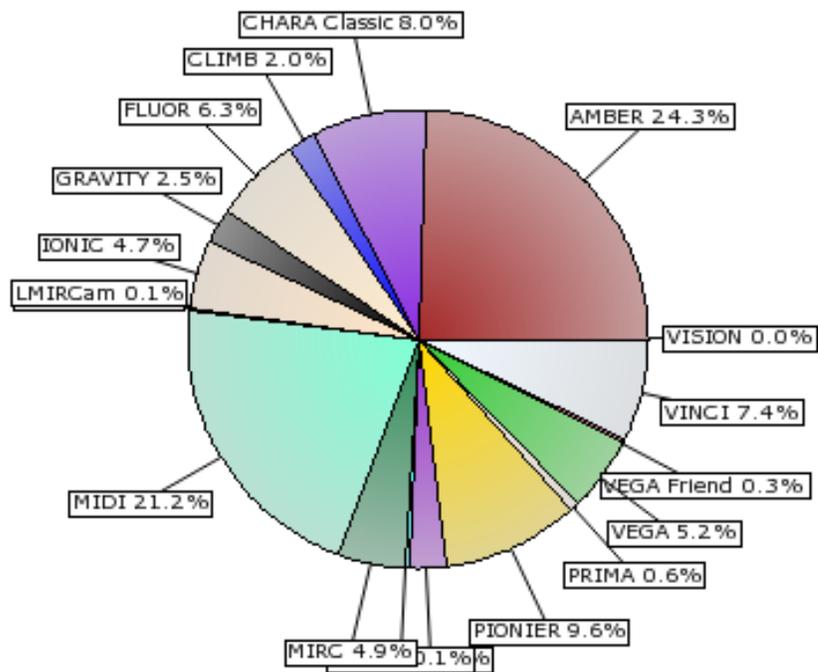
Installation of MATISSE warm-optics in the VLTI Lab (November 2017)

	nTel	Band	Spectral Res.	Available
MIDI	2	N	20-230	2001-2015
AMBER	3	(J)HK	30-12000	2003-2018
PIONIER	4	H	5-30	2010
GRAVITY	4	K	22-4000	2016
MATISSE	4	LMN	30-4000	2018

Current Status of VLTI



AMBER and MIDI deserve their retirement



Interferometric papers by instrument
(source : JMMC bibDb)

	nTel	Band	Spectral Res.	Available
MIDI	2	N	20-230	2003-2015
AMBER	3	(J)HK	30-12000	2005-2018
PIONIER	4	H	5-30	2012
GRAVITY	4	K	22-4000	2016
MATISSE	4	LMN	30-4000	2019

MATISSE : a lot more than MIDI successor !



Pierre Antonelli (Project Manager), Bruno Lopez (PI), and Philippe Berio (DRS) in the MATISSE integration room in Nice

MIDI	MATISSE	
2 Telescopes	4 Telescopes	
Co-axial	Multi-axial	
N band	L&M bands	N band
8-13 μ m	3-5 μ m	8-13 μ m
R = 30, 230	R = 34, 506, 950 (4000)	R = 30, 220
Raytheon IBC	HAWAI-2RG	AQUARIUS
320x240	2048x2048	1024x1024

The science cases of MATISSE



Protoplanetary disk



Feature	Wavelength (μm)
<i>L- and M-bands (~ 2.8–5.0 μm)</i>	
H ₂ O (ice)	3.14
H ₂ O (gas)	2.8–4.0
H lines (Br- α , Pf- β)	4.05, 4.65
PAHs	3.3, 3.4
Nano-diamonds	3.52
CO fundamental transitions	4.6–4.78
CO (ice)	4.6–4.7
<i>N-band (~ 8.0–13.0 μm)</i>	
Amorphous silicates	9.8
Crystalline silicates (olivines and pyroxenes)	9.7, 10.6, 11.3, 11.6
PAHs	8.6, 11.4, 12.2, 12.8
Fine structure lines (e.g., [S IV], [Ne III], [Ne II])	10.5, 10.9, 12.8

- Study temperature and density profile in the disk (in continuum L, M, and N bands)
- Detect gaps and other structures in the disk
- Locate chemical elements in the disk such as water, ice, CO,...

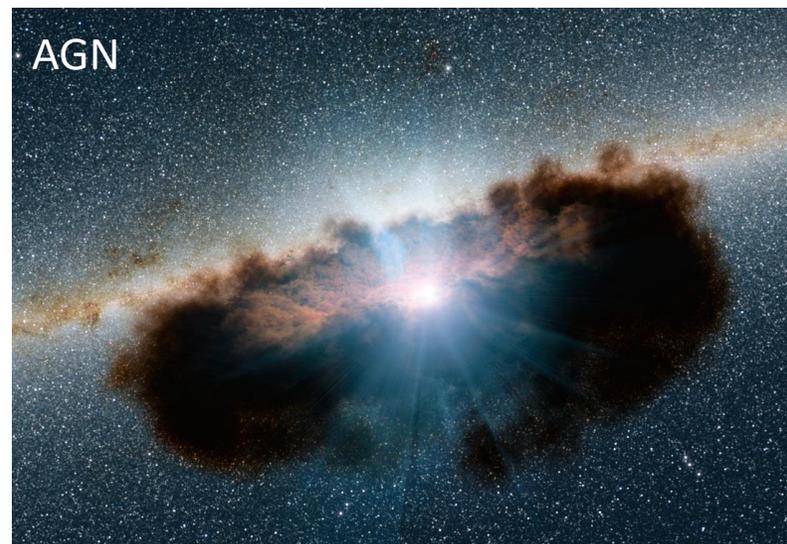
The science cases of MATISSE



Protoplanetary disk



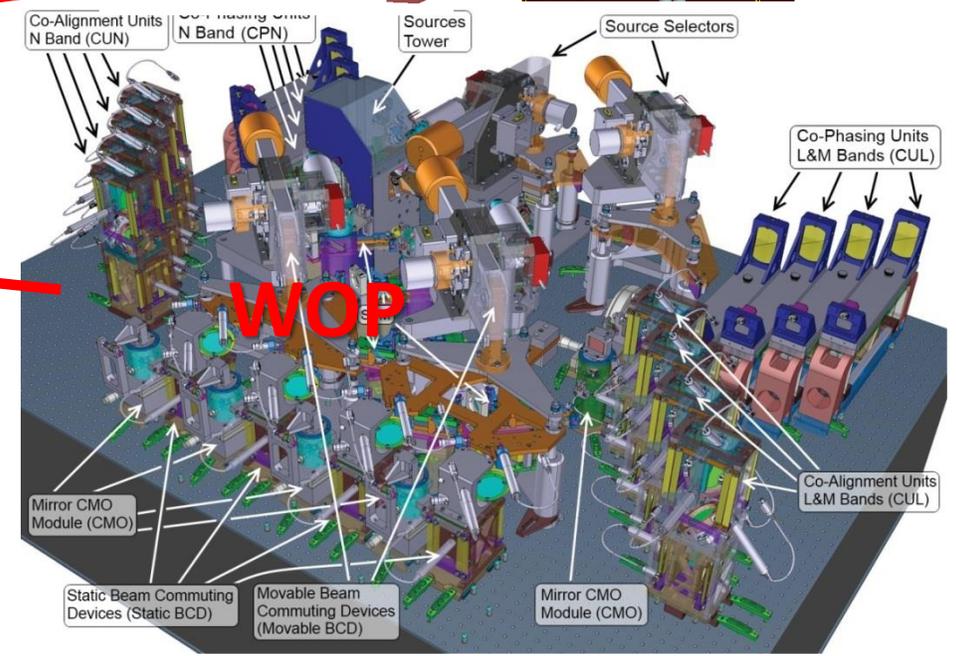
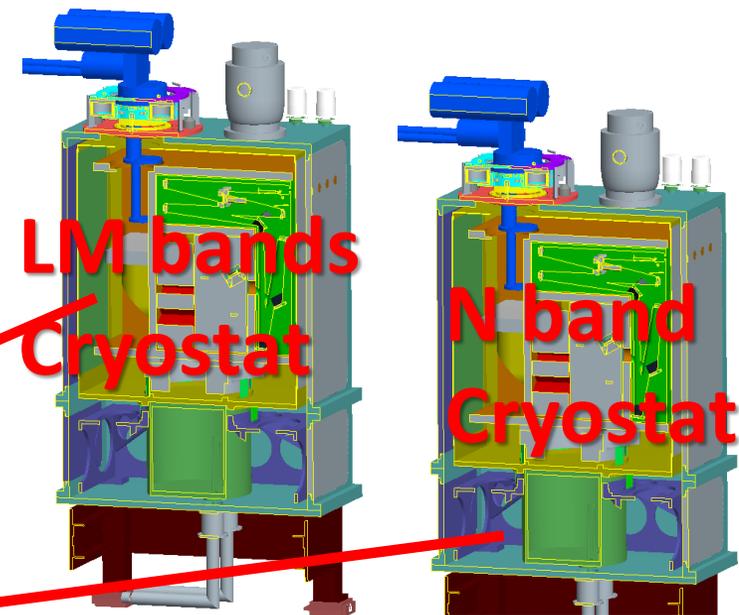
AGN



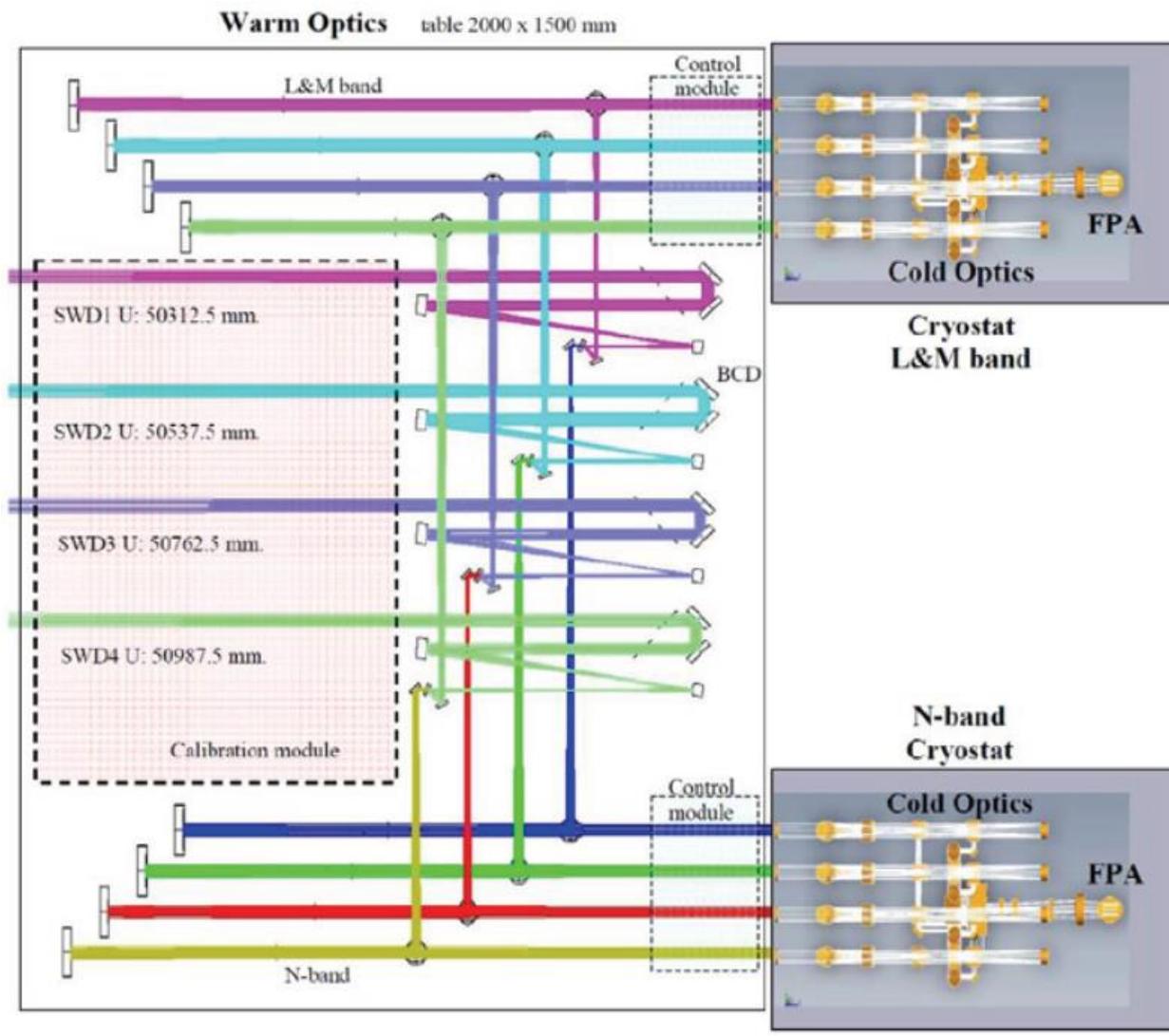
Evolved stars



MATISSE WOP & Cryostats

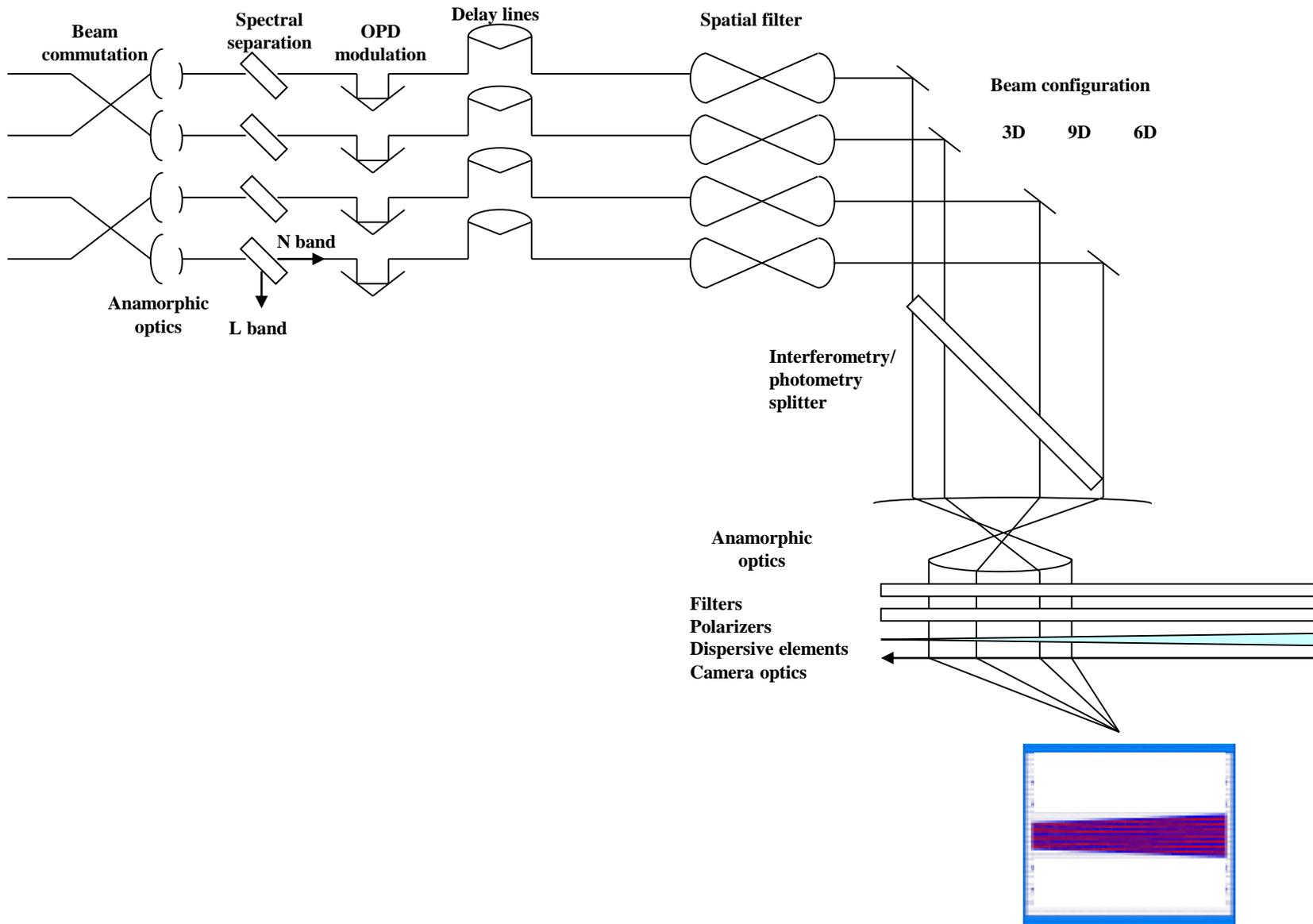


MATISSE optical-path



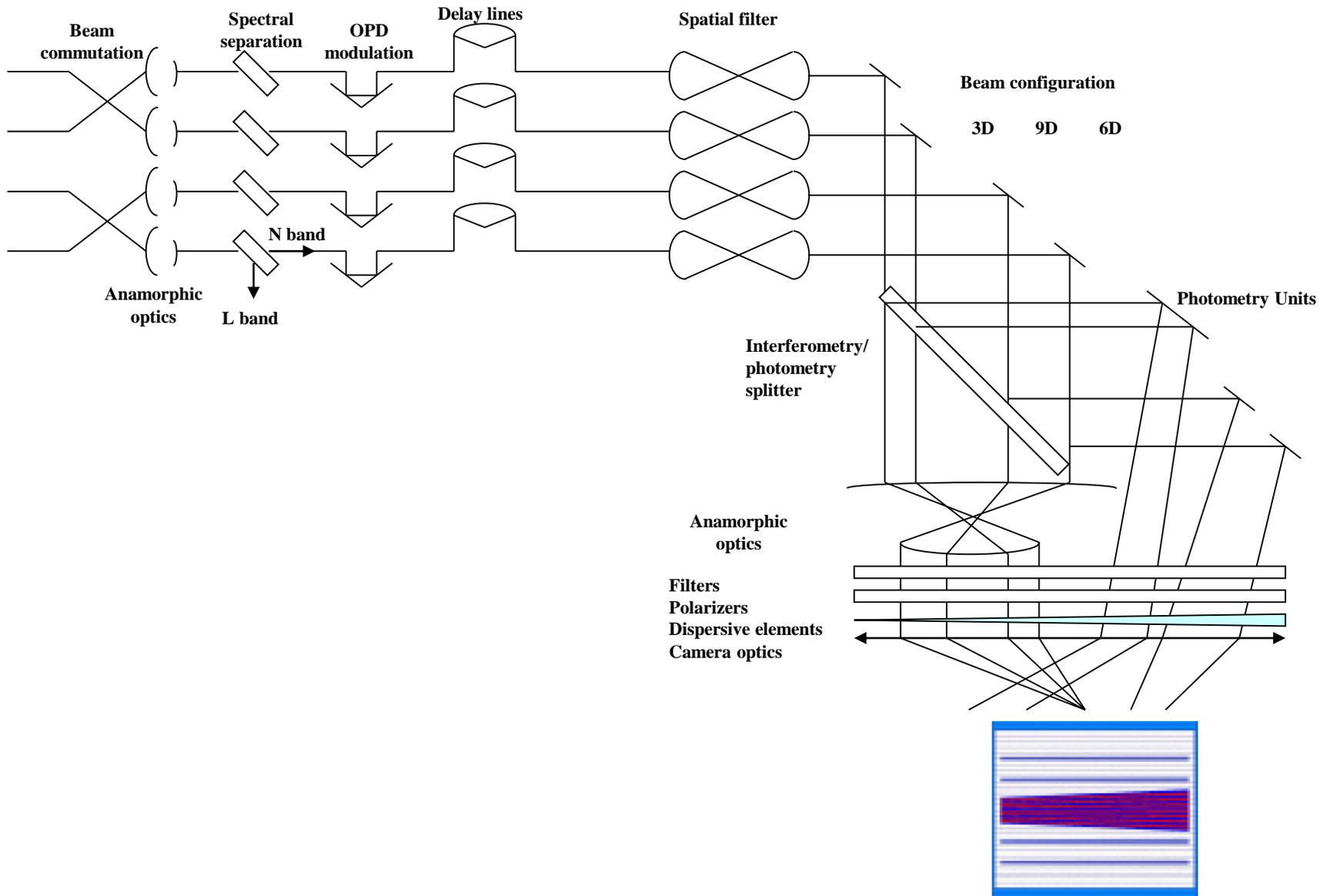


Principle of MATISSE





Principle of MATISSE



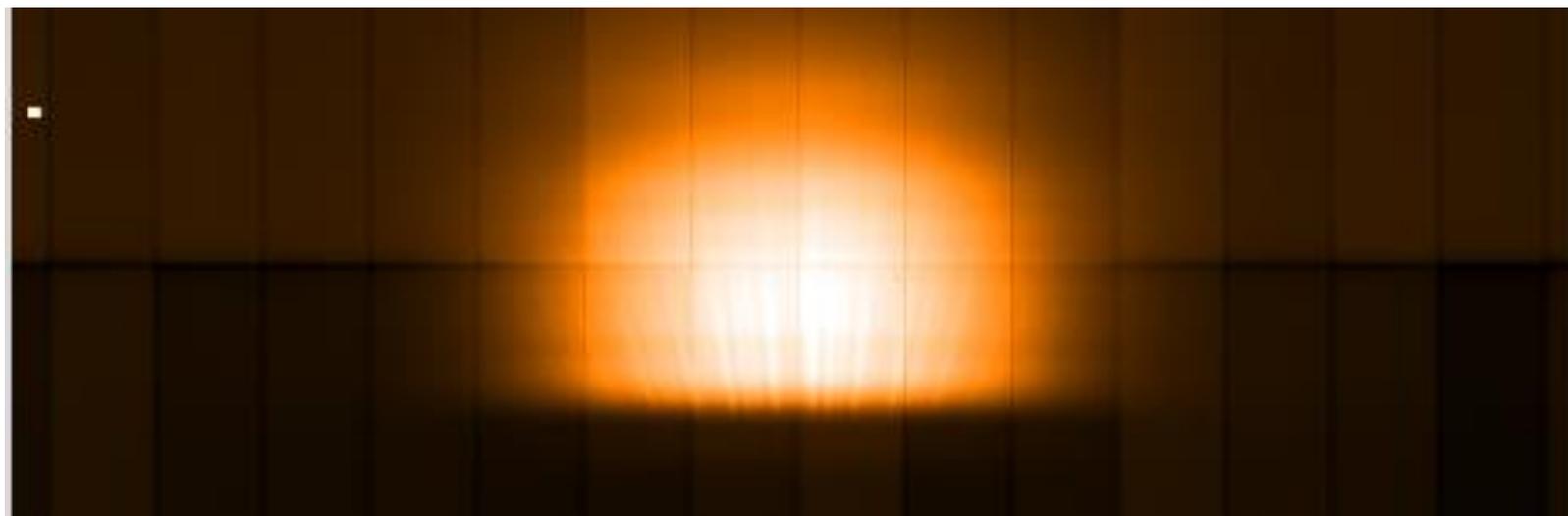
MATISSE Low Resolution Fringes



L&M bands



N band



MATISSE Fringe coherencing software

File Std. Options AlgoL AlgoN DelayLines **Help**

MATISSE Fringe Panel Status Idle Current Template None Spectra Processing time per frame (ms) 17.1 14.4

Searching & Tracking options

Master Band: L DL Mode: OFF Tracking Gain: 0.5 Searching options: nIdle 5 nSteps 15 Size 15

DL1 OFF DL2 OFF

DL3 OFF DL4 OFF

RAW Low: 4071.00 High: 16105.00 Auto Cuts Min/Max

Camera: displayL11 Status: Attached Frame Type: Object

Frames Integration

Incoherent: 10 10 Set Coherent: 10 10 Set

InterSize: 512 512 DIL: LOW FIL: LM wMn: 3 wMx: 5 pixToPist: 4.2 Coher. length: 129

L (MASTER) Frame=271961

Photometry

BSL1 25 (%) BSL2 28 (%) BSL3 23 (%) BSL4 25 (%)

Flux (Jy)

957.1

N (SLAVE) Frame=373456

Photometry

BSN1 0 (%) BSN2 0 (%) BSN3 0 (%) BSN4 0 (%)

Flux (Jy)

-44.4

Fringe plots Options

X range: 1000 Set

Y range: 1000 Set

Cursor Information: X: VALUE: LAM: OPD:

B1+drag = select region to zoom in, B2 = highlight selected plot, B3 = reset zoom



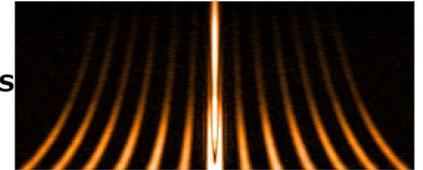
RAW



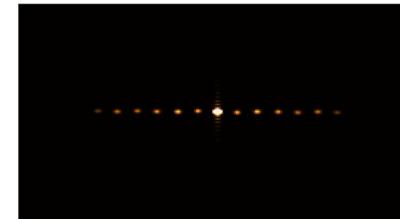
CLEAN



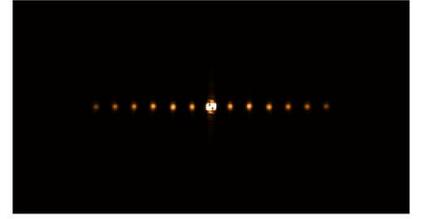
FFTXMODULUS



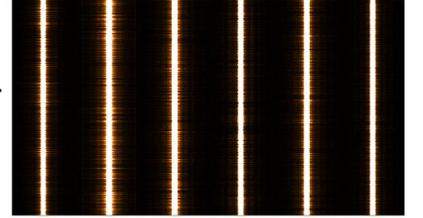
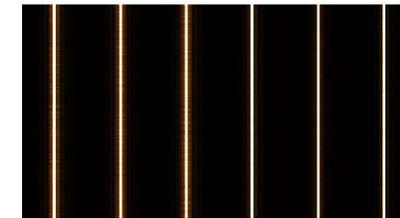
FFTXPHASE



FFT2D



WATERFALL





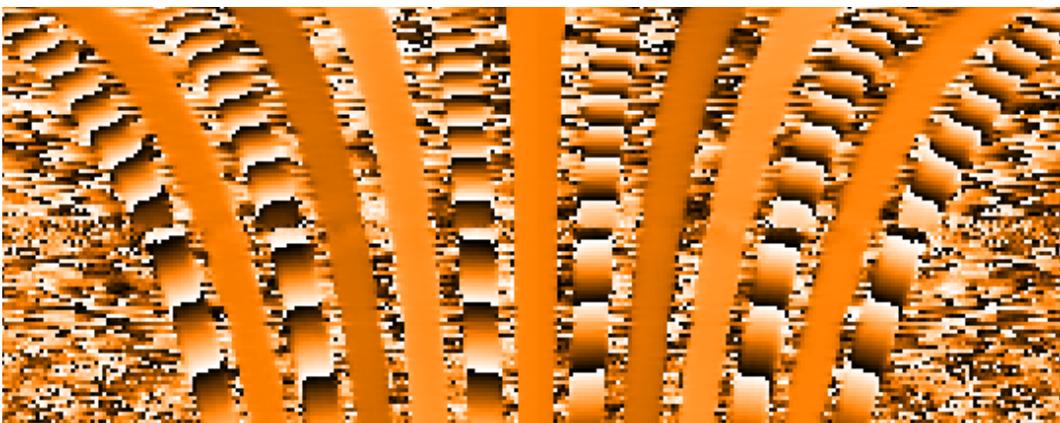
MATISSE Fringe coherencing software

Non-zero-OPD Fringes

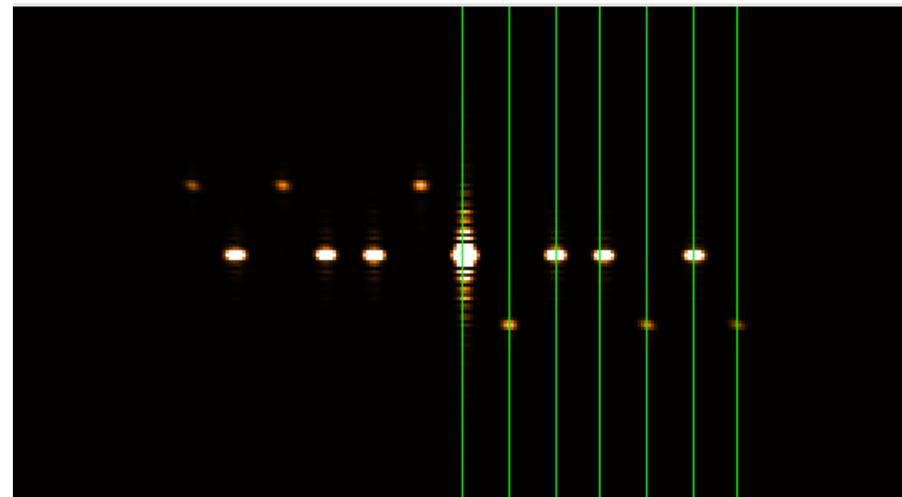
Clean Fringes



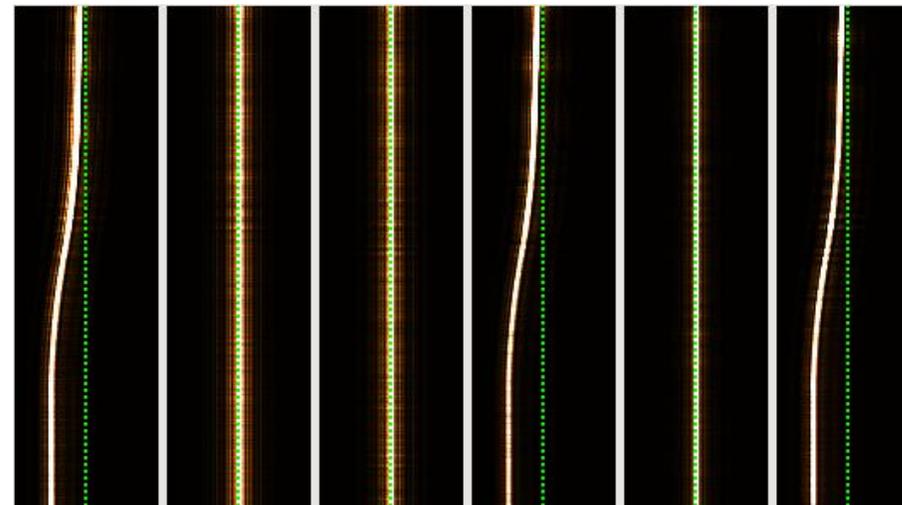
FFTX phase



FFT2D modulus



Fringe peaks waterfall



Integration in Paranal (October-December 2017)



Your Talk Title Here



“First Light” (February 18, 2018)



Your Talk Title Here



“First Light” (February 18, 2018)



Your Talk Title Here





“First Light” (February 18, 2018)

mtopanFringes - @wmt

File Std. Options Options Help

MATISSE Fringe Panel Status Idle Current Template None Show Spectra

Path 7.970 SNR 32481 OFF

0.1
0.05
0
-0.05
-0.1

1

L (MASTER)
Frame=999

Frames Integration
Incoherent: 1
Coherent: 1
Apply

intertSize 512 512
apod 0 512 512
DIL MED FIL LM
wMn 3 wMx 5
pixToPist 35.5
Coher. length 2009
Algo. FULL

FFT2D Low: 0.00 High: 0.01 Auto Cuts Min/Max

Saturated

Camera: displayL5
Status: Attached
Frame Type: Object
Show Graphics

Cursor Information
X:
Y:
VALUE:
LAM:
OPD:

Photometry (L)
100 10 100
1 2
0 0
100 100
0 0

Pos. -11.7 SNR 19698 Pos. -34.1 SNR 32481 Pos. 35.79 SNR 11813 Pos. 30.59 SNR 13426 Pos. 9.445 SNR 14751 Pos. -1.15 SNR 20130
BSx3-BSx4=U3-U4 BSx1-BSx2=U1-U2 BSx2-BSx3=U2-U3 BSx2-BSx4=U2-U4 BSx1-BSx3=U1-U3 BSx1-BSx4=U1-U4

SNR Limit 5
Set

Limit SNR 2.5
Set

Pos. 3.757 SNR 10.34 Pos. -5.36 SNR 5.573 Pos. -5.38 SNR 25.68 Pos. 7.033 SNR 12.05 Pos. -815. SNR 0.343 Pos. 37.55 SNR 0.628

Fringe plots Options
X range: 2000 Set
Normalize by plot
Normalize by band
Y range: 10

Show Graphics
Frame type: Object
Camera: displayN5
Status: Attached
Saturated

FFT2D Low: 0.00 High: 0.01 Auto Cuts Min/Max

Photometry (N)
100 10 100
0 0
100 100
0 0

Path 13.13 SNR 19698 OFF

0.1
0.05
0
-0.05
-0.1

1

Path 4.382 SNR 20130 OFF

0.1
0.05
0
-0.05
-0.1

1

Frame=5000
N (SLAVE)

Frames Integration
Incoherent: 1
Coherent: 1
Apply

intertSize 512 512
apod 0 512 512
DIN LOW FIN OPEN
wMn 8 wMx 13
pixToPist 10.0
Coher. length 327
Algo. FULL

Diagram showing tracking system components: UT1-U4, DL1-DL4, BSL1-BSL4, BSN1-BSN4, IP1-IP7, BCD1/2 Out.

mtopanCamera - @wmt

File Std. Options Help

HAWAII-2GR (LM)
Camera: NIRC1 Attached

Scale: FIT 1x Auto

Low: -76.00 High: 2455.00
Auto Cuts Min/Max

X: Y: VALUE:

AQUARIUS (N)
Camera: NIRC2 Attached

Scale: 2x 2x Auto

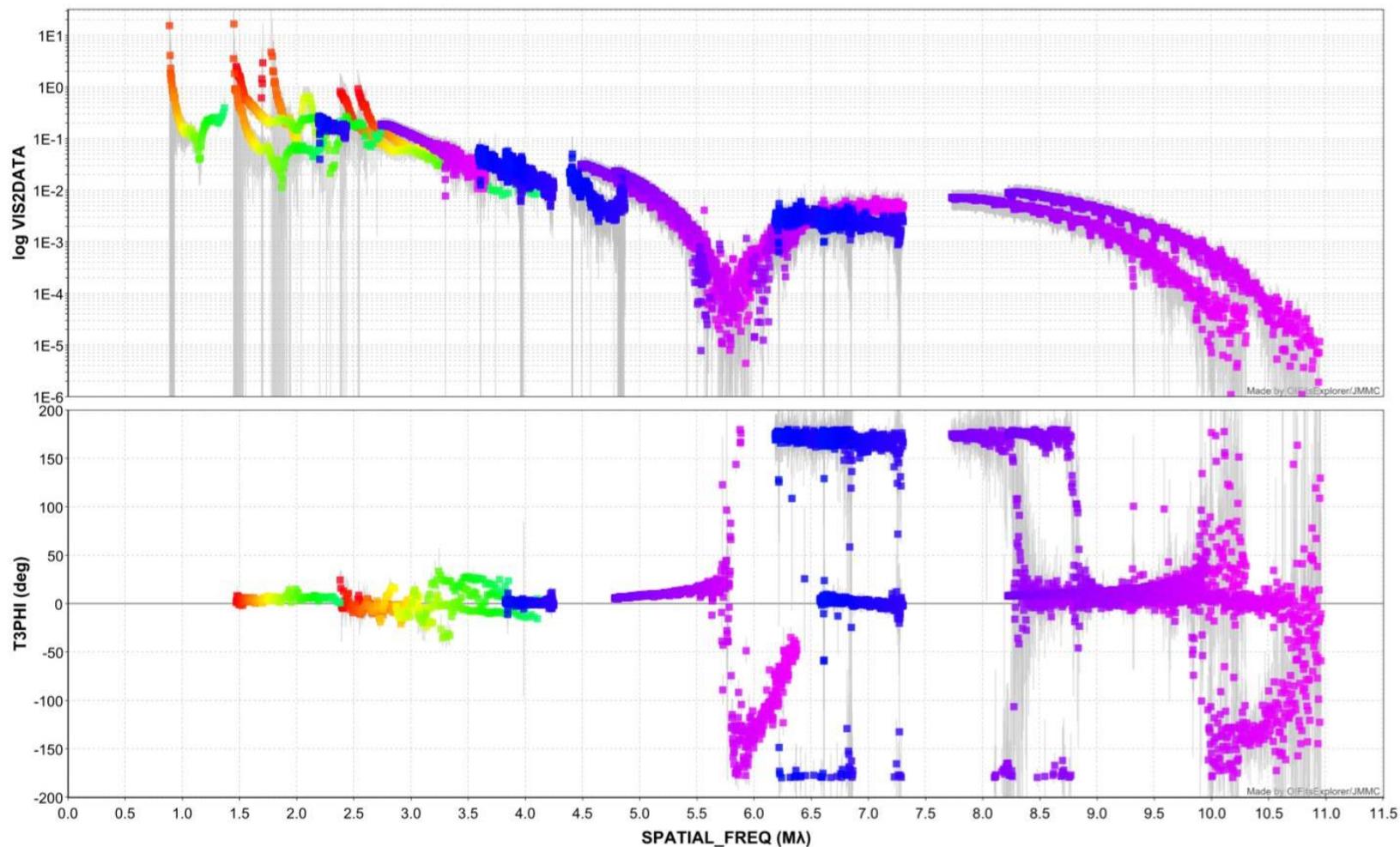
Low: -112.00 High: 125.00
Auto Cuts Min/Max

X: Y: VALUE:



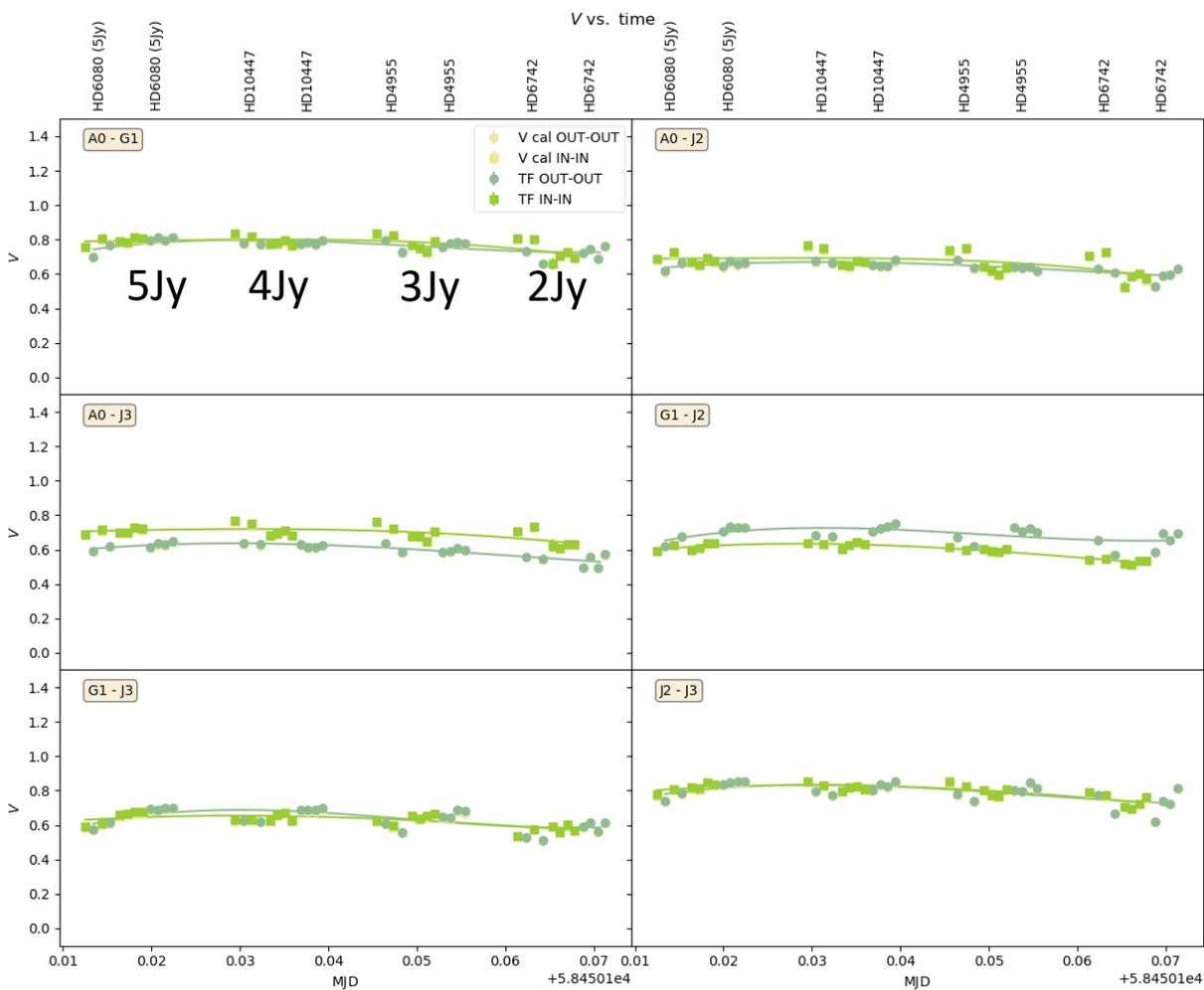
“First Light” (February 18, 2018)

Betelgeuse

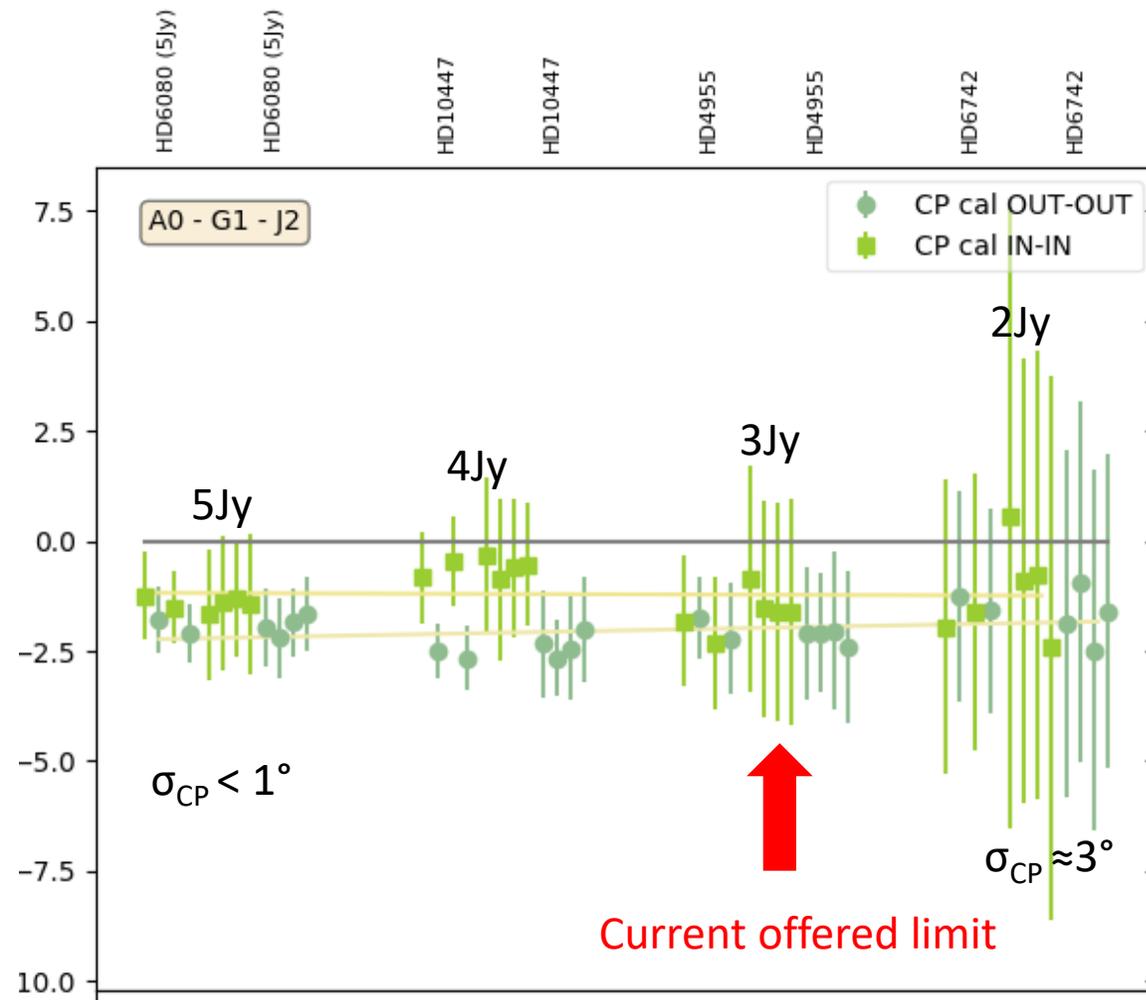


3 μm (L)
 5 μm (M)
 8 μm (N-)
 13 μm (N+)

MATISSE Commissioning

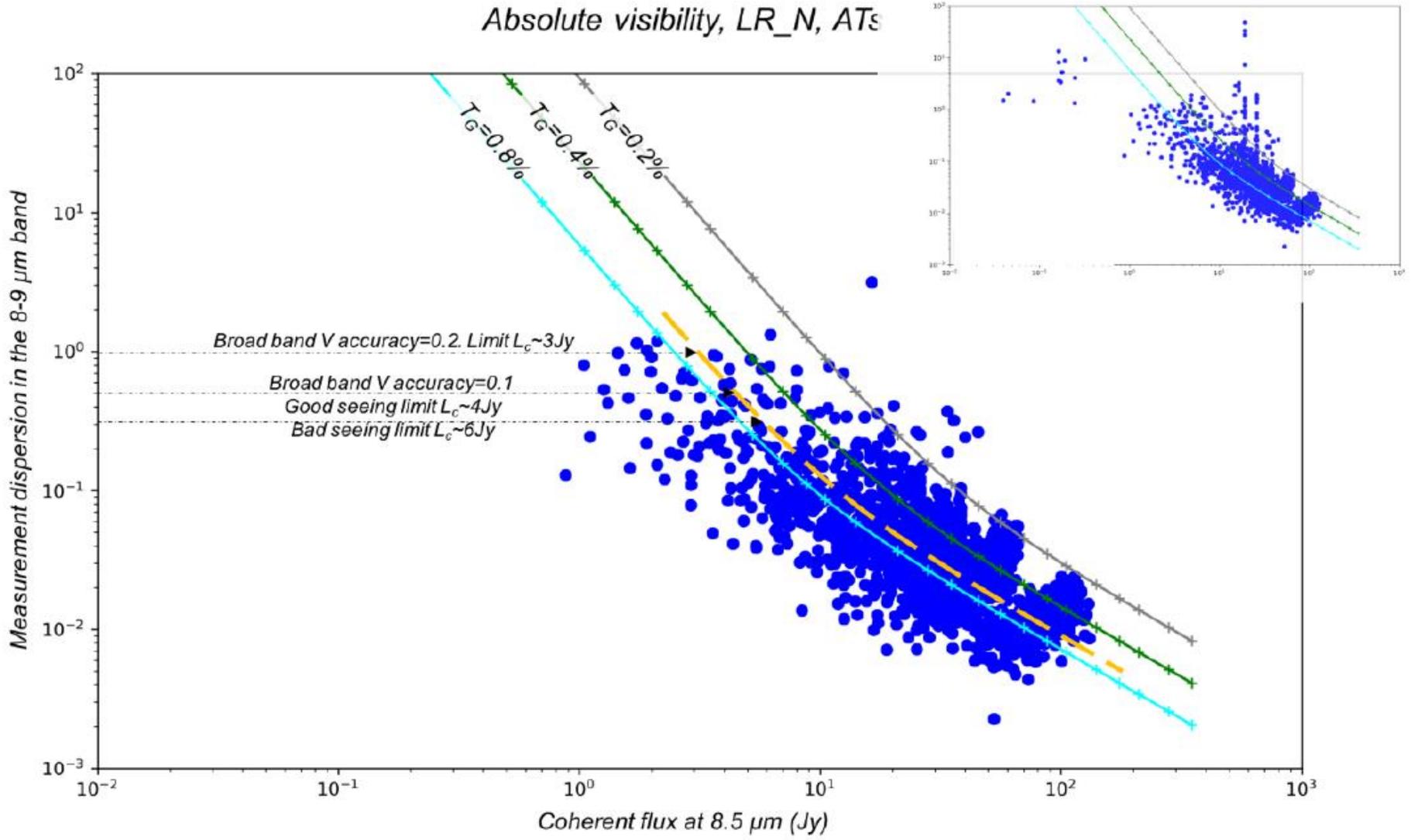


L-band visibility on ATs



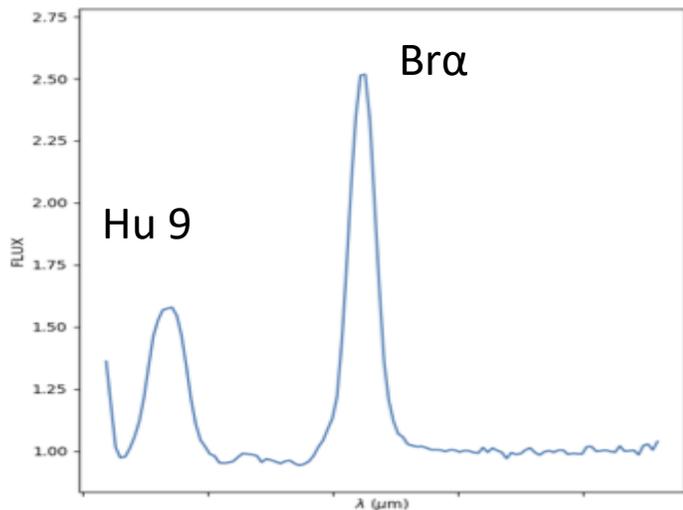
L-band Closure phase on ATs

MATISSE performance

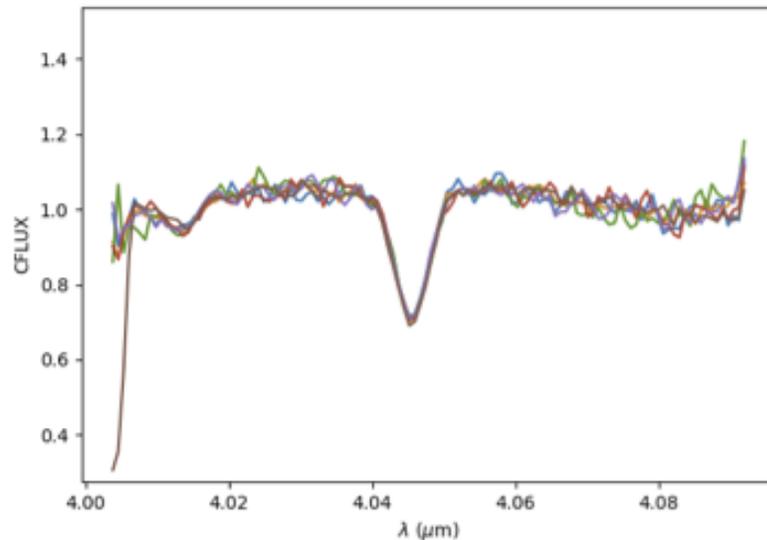




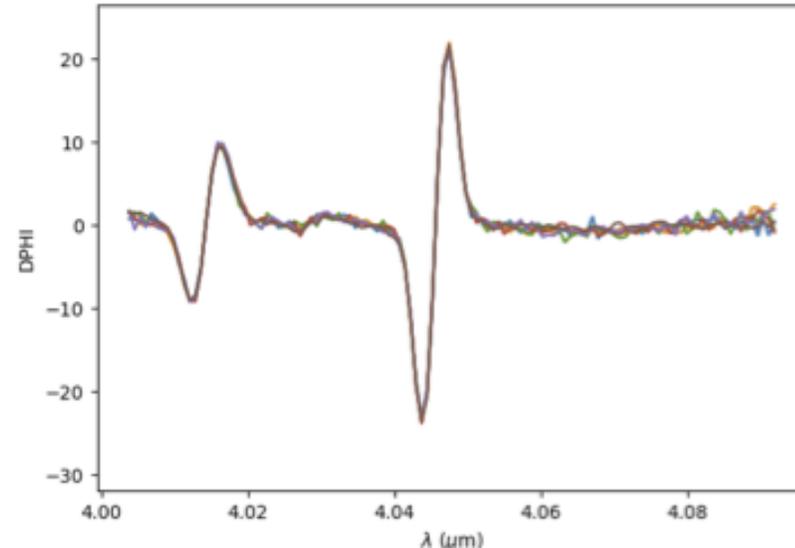
Observation in L-Band High Resolution (R=950) Example on an emission line star



Br α Line Profile (+ Hu 9)



Visibility

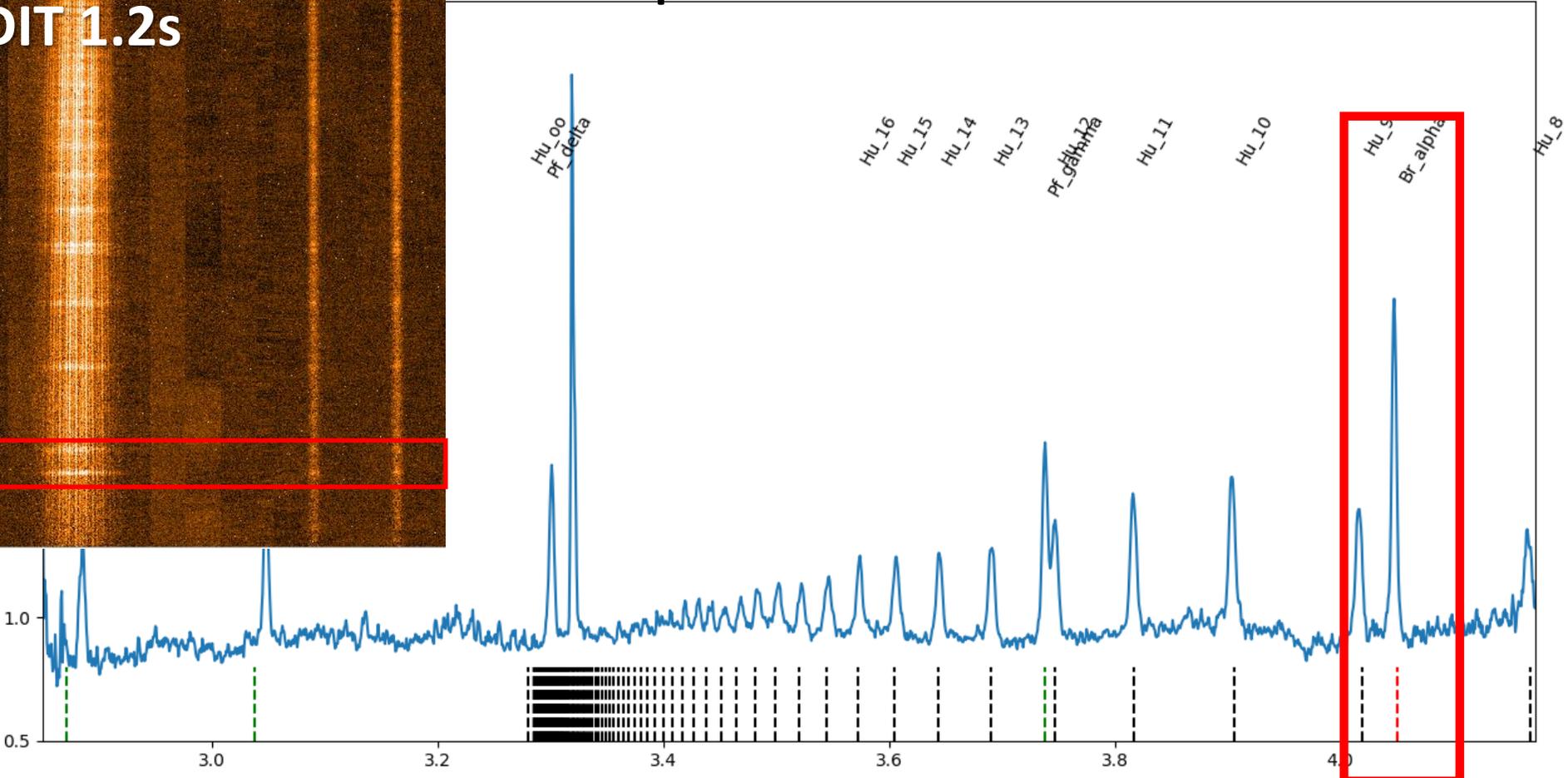
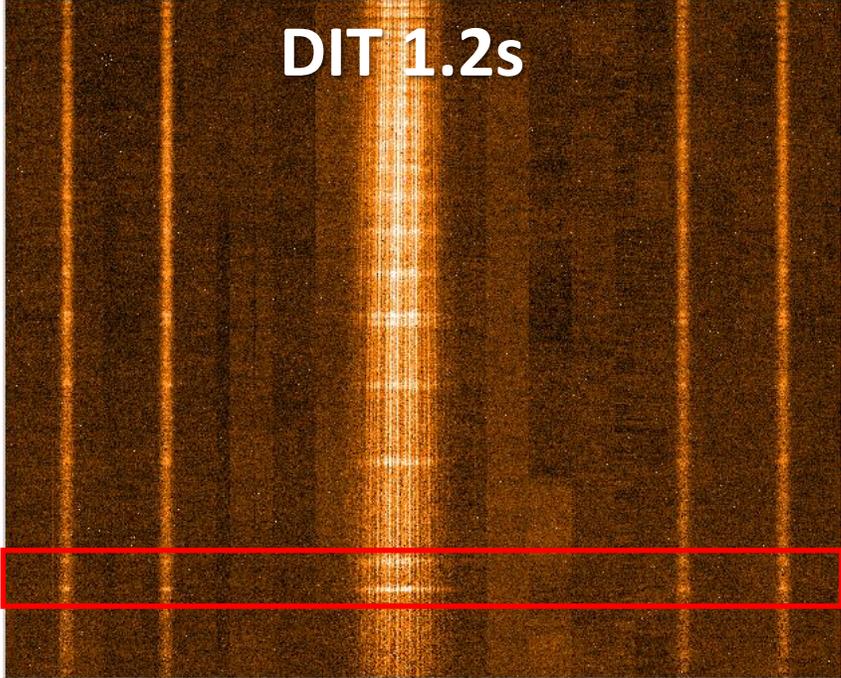


Differential Phase

Current Spectral range in HR mode limited by detector read time
DIT=111ms \leftrightarrow 0.1nm



Observation in L-Band High Resolution (R=950) Example on an emission line star



Could be extended using GRAVITY as external Fringe Tracker

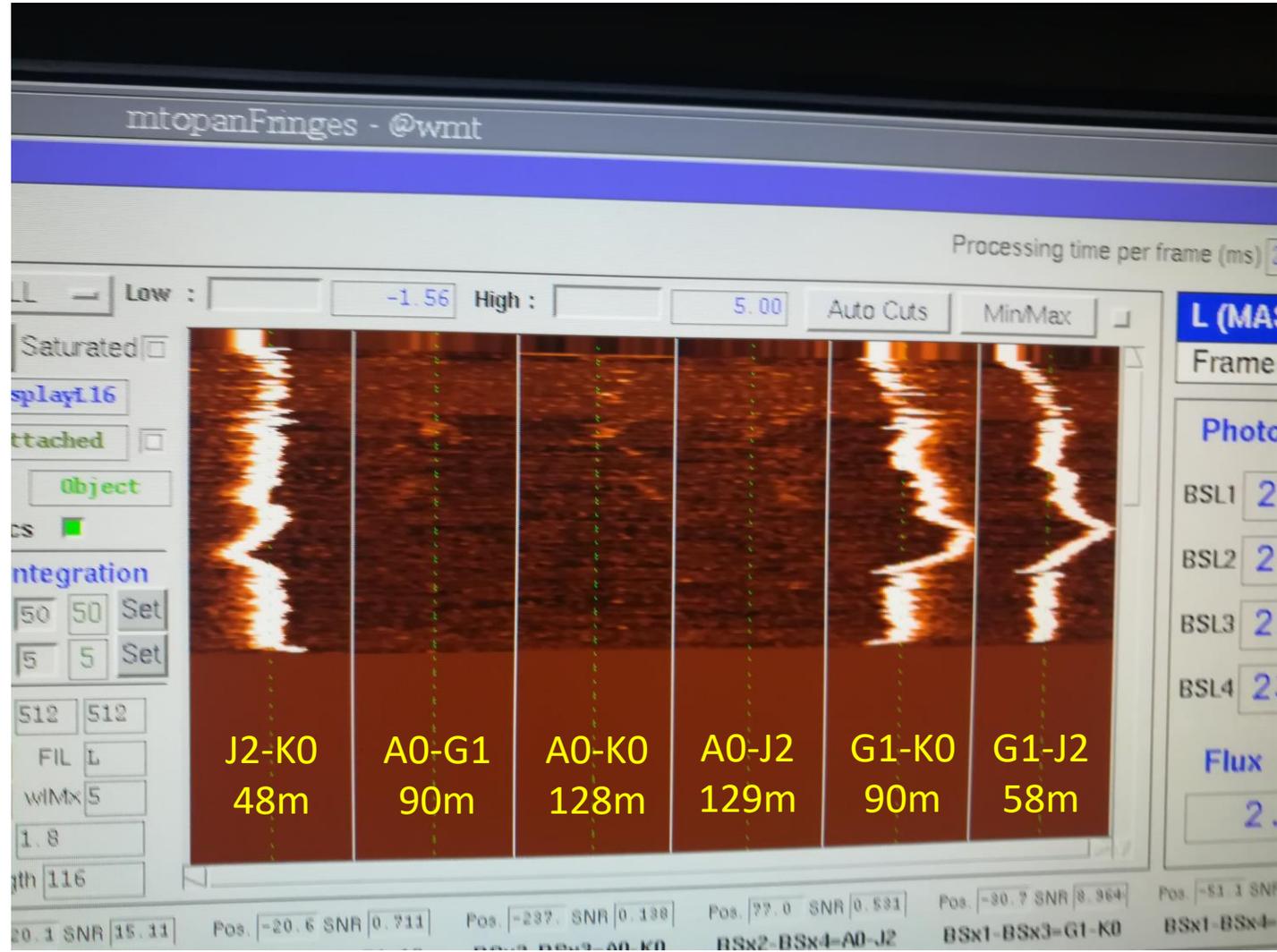


GRAV4MAT



Tests on AGNs

AT L-band Fringes acquisition

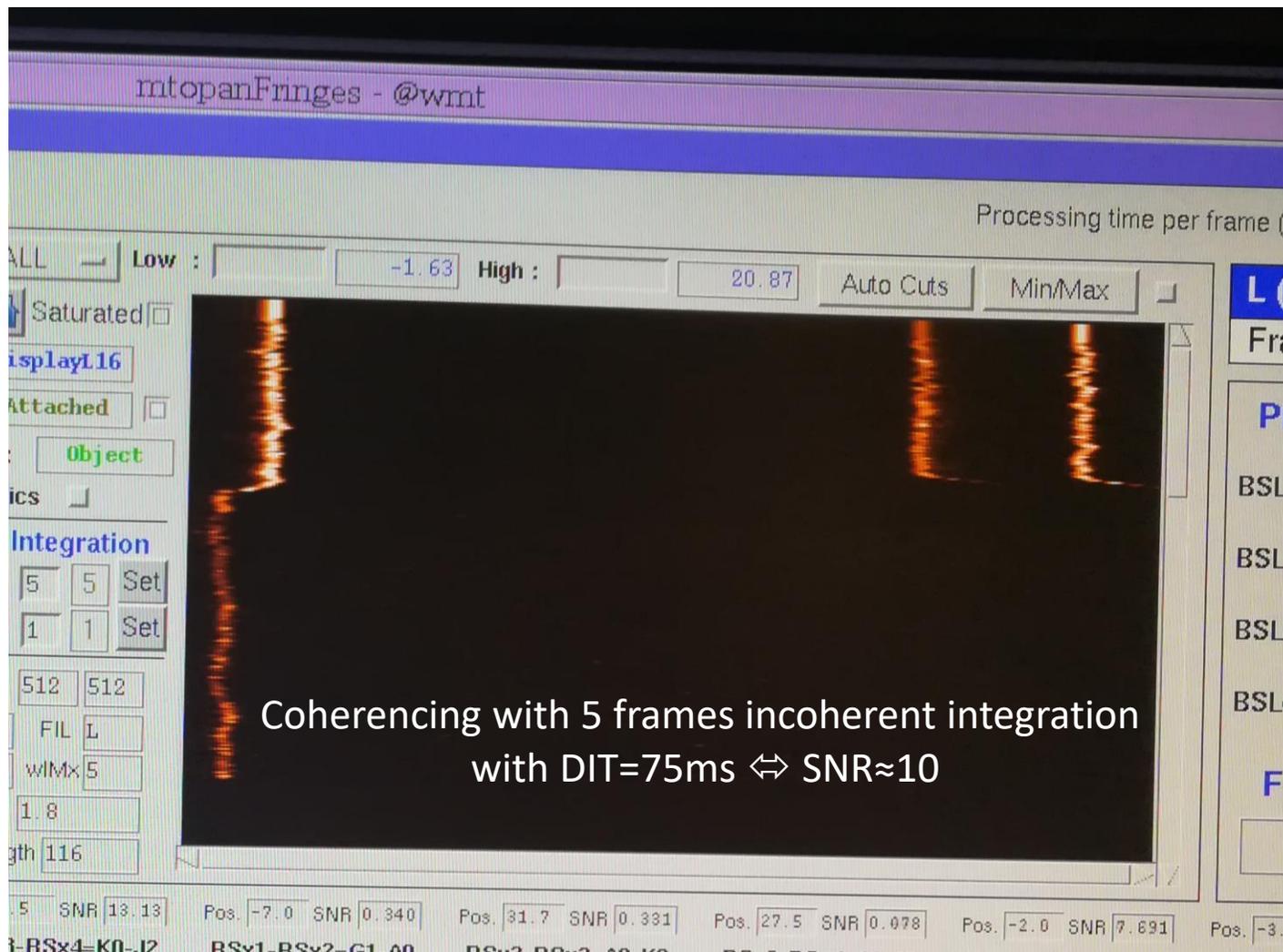


≈ 2Jy



Tests on AGNs

AT L-band Fringes coherencing



≈ 2Jy

MATISSE First Image (December 2018)



Imaging Commissioning Run

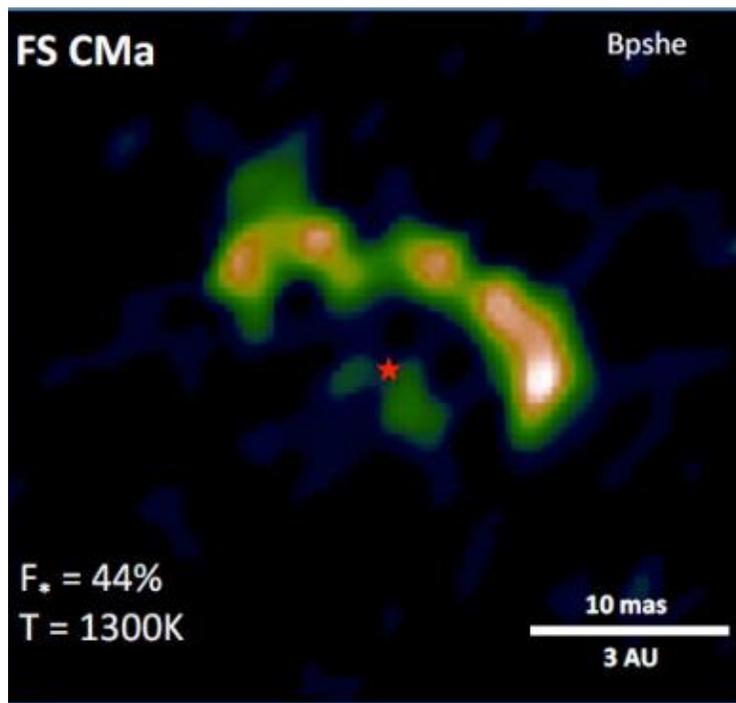
10 nights of observation

All 4 offered AT configurations :

- Small : 12-35m
- Medium : 40-105m
- Astrometric:58-129m
- Large : 90-132m

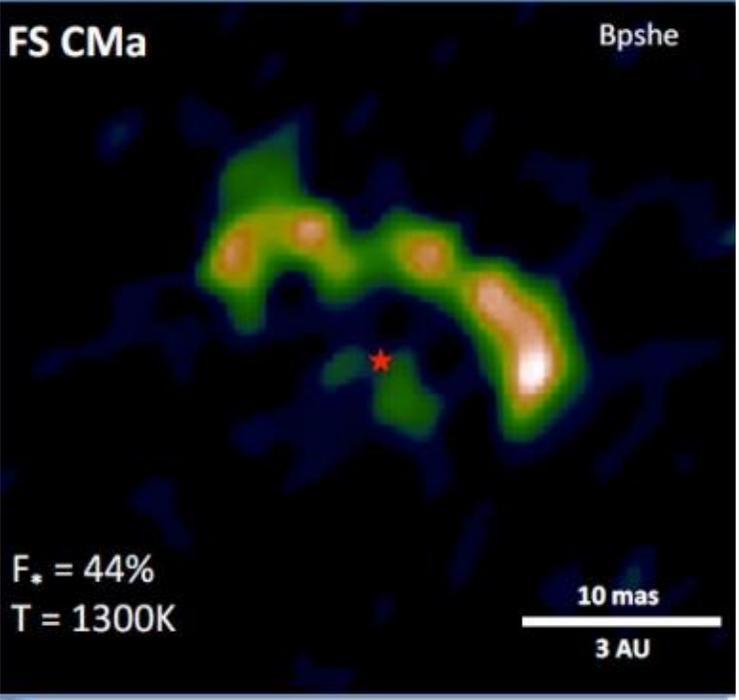
3 main targets (well studied) :

- FS CMa : YSO or B[e]? => circumstellar disk
- R Scl : AGB
- Betelgeuse : to test HR imaging capability

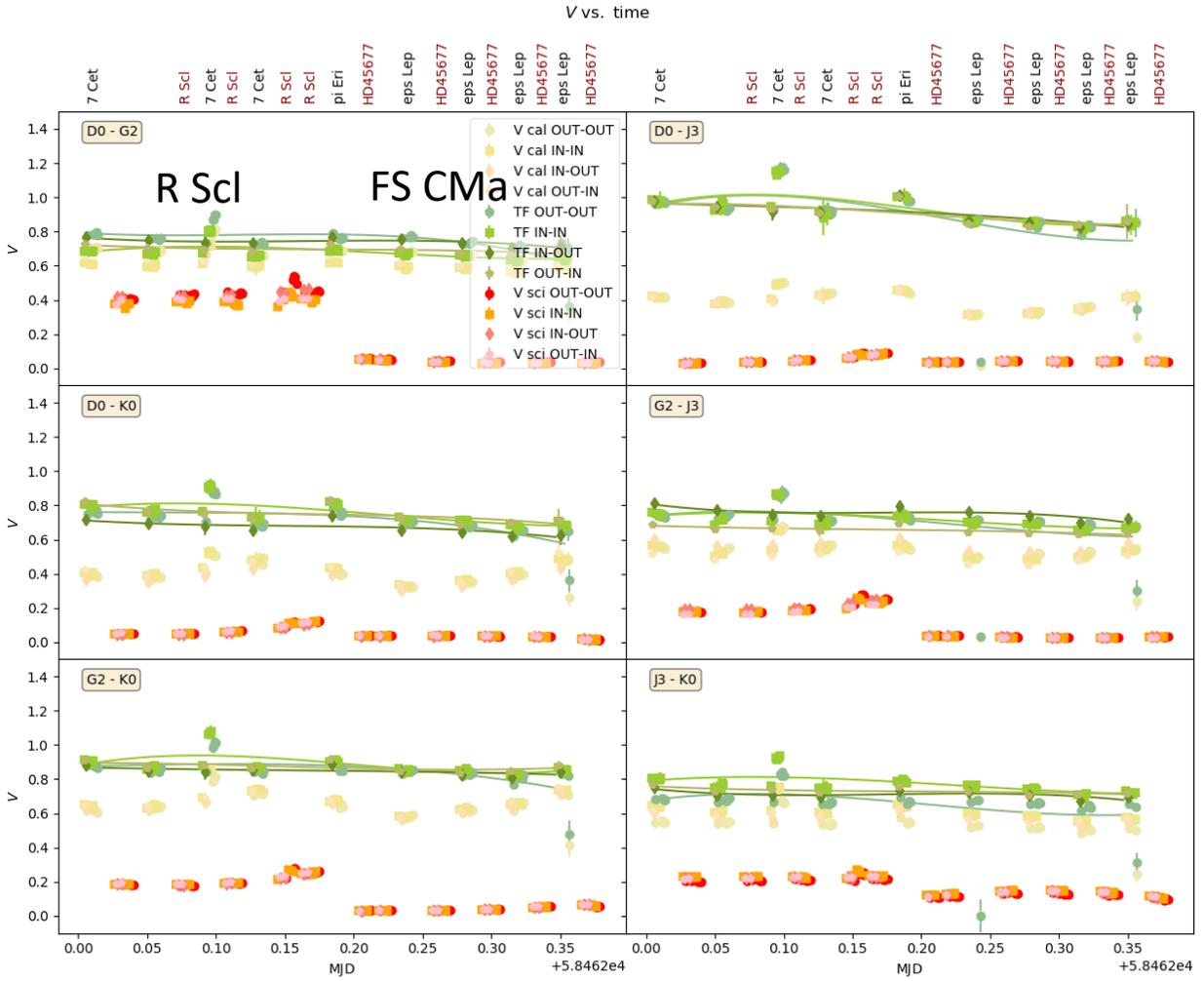


PIONIER image of FS Cma (HD45677)
Circumstellar disk (either B[e] or Herbig)

MATISSE First Image (December 2019)

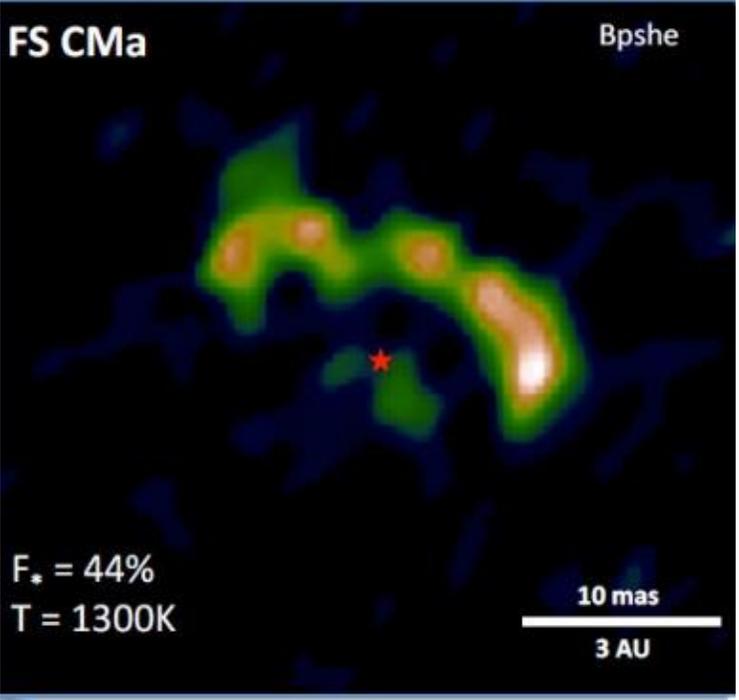


PIONIER image of FS Cma (HD45677)
Circumstellar disk (either B[e] or Herbig)

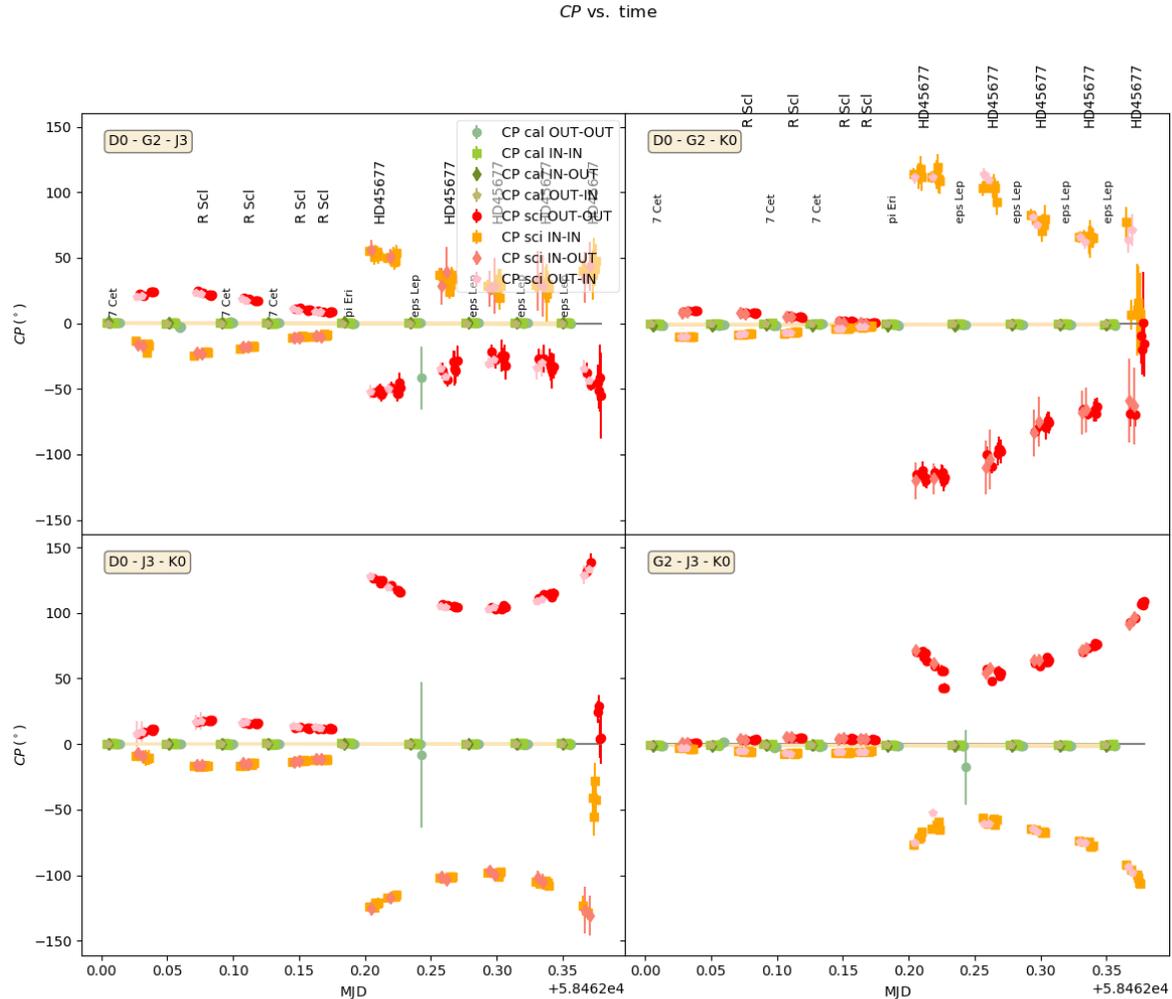


L-Band Transfer function in visibility

MATISSE First Image (December 2019)

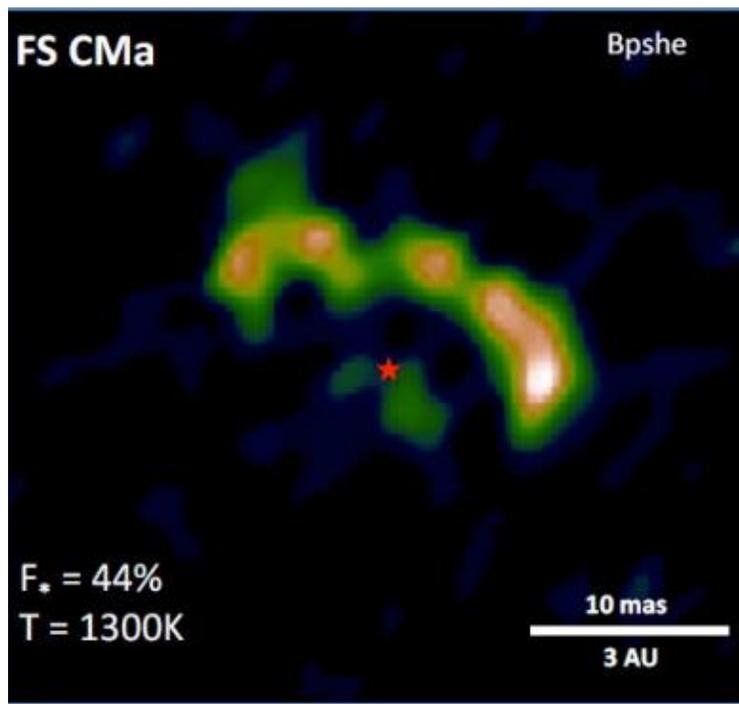


PIONIER image of FS Cma (HD45677)
Circumstellar disk (either B[e] or Herbig)

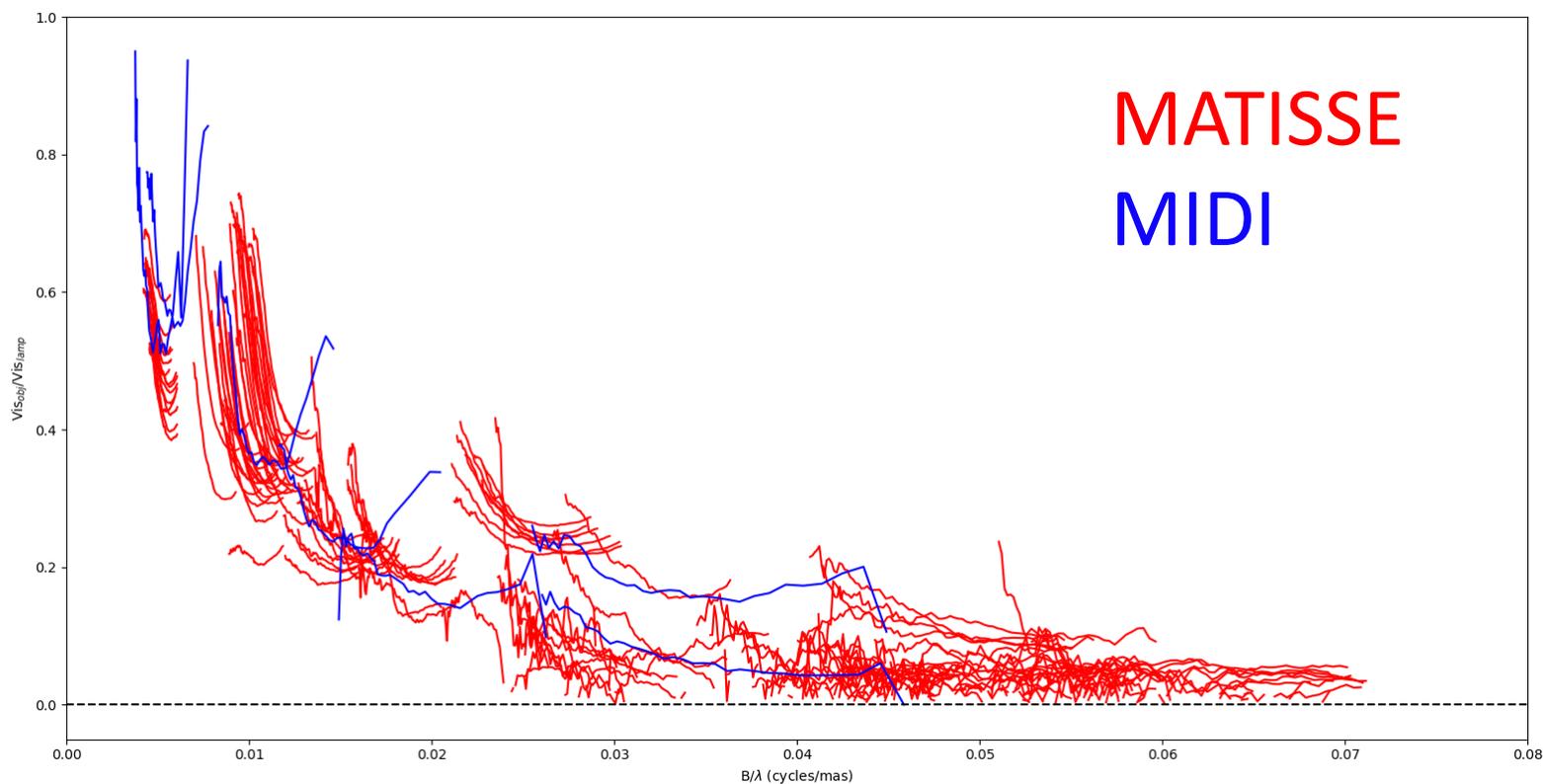


L-Band Transfer function in Closure Phase

MATISSE First Image (December 2019)

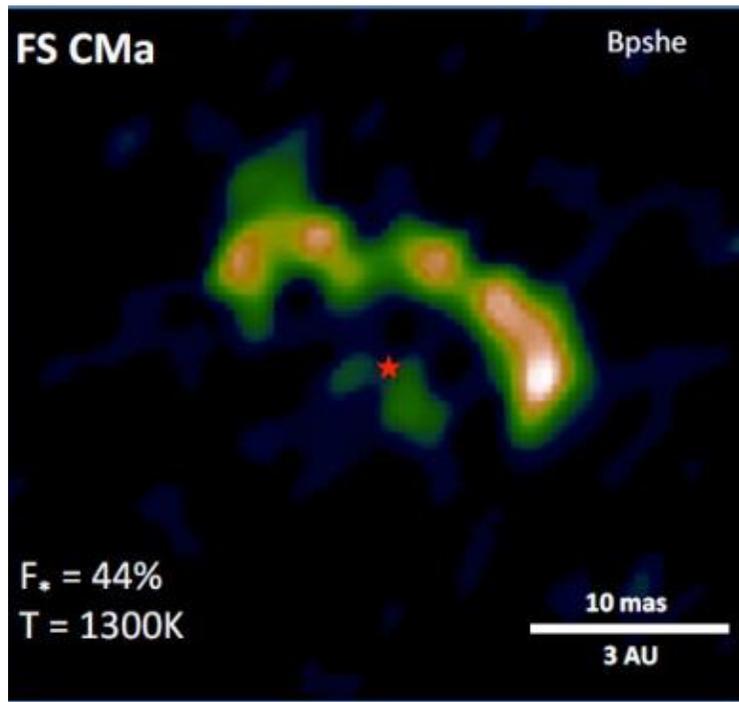


PIONIER image of FS Cma (HD45677)
Circumstellar disk (either B[e] or Herbig)

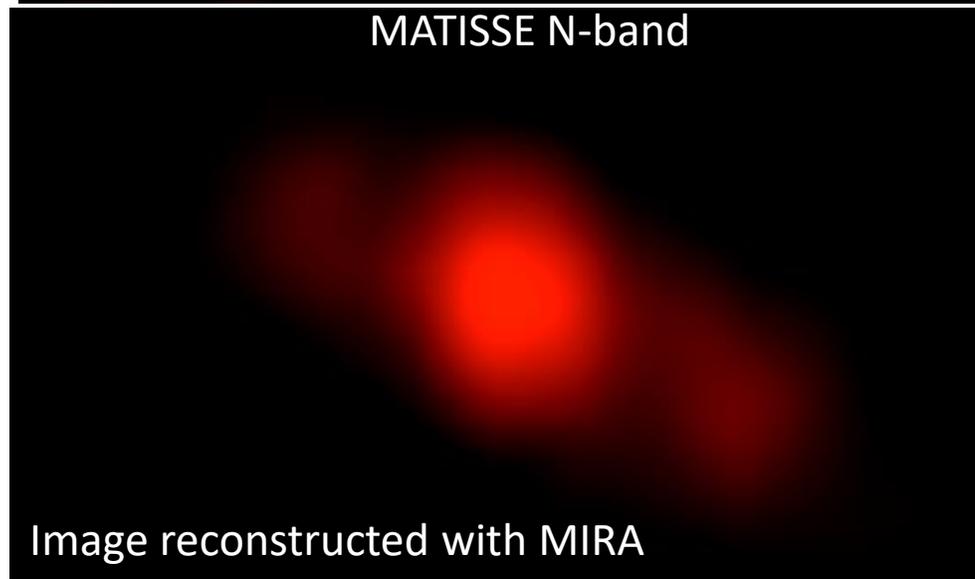
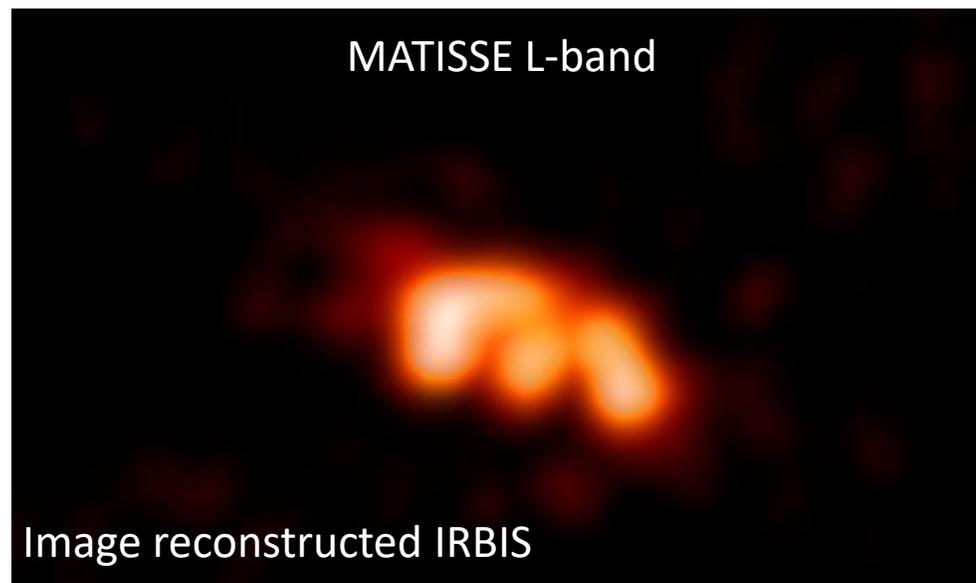


N-Band Calibrated V as a function of spatial frequency

MATISSE First Image (December 2019)



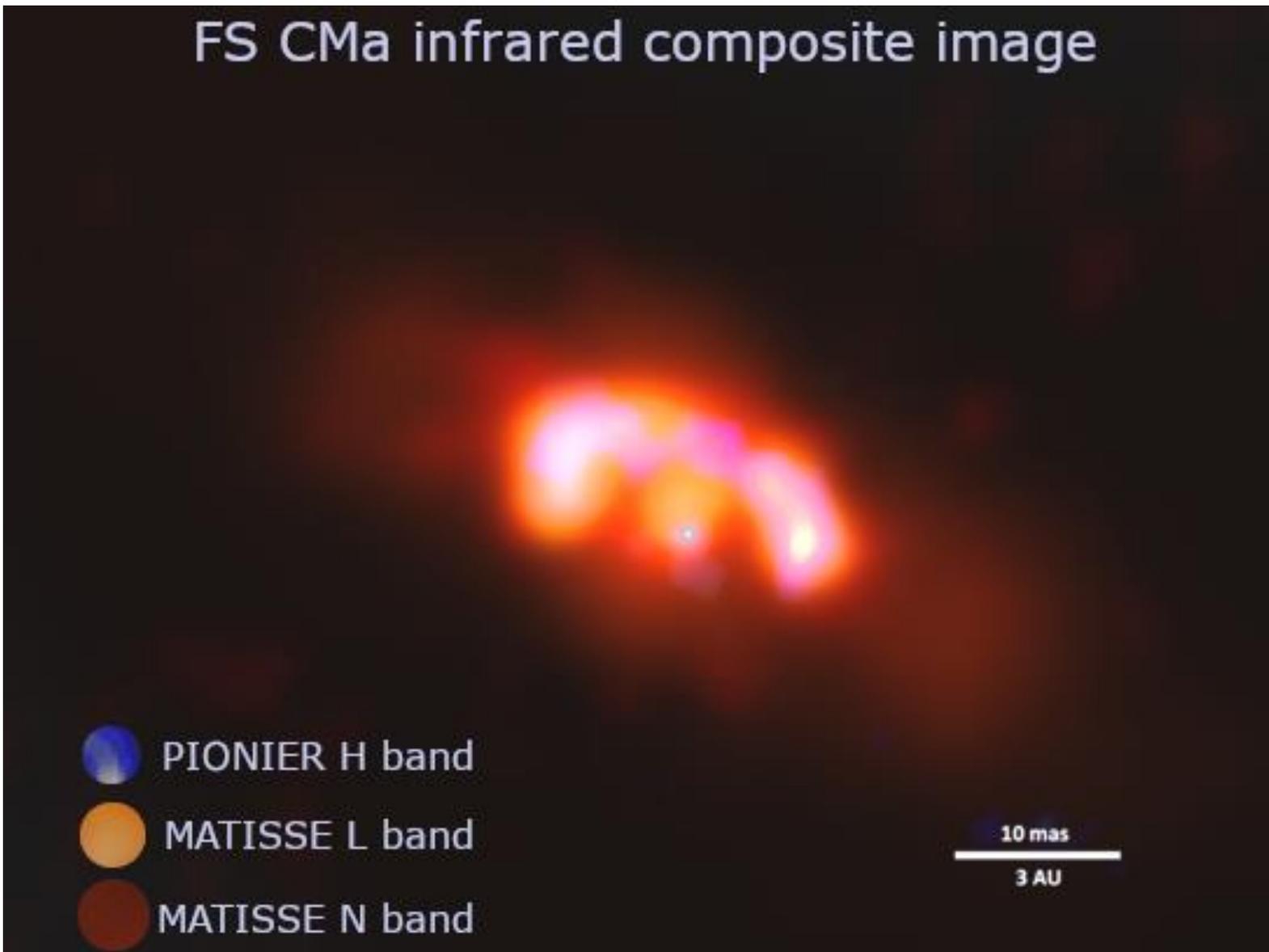
PIONIER image of FS Cma (HD45677)
Circumstellar disk (either B[e] or Herbig)





MATISSE First Image (December 2019)

FS CMA infrared composite image



What's next?

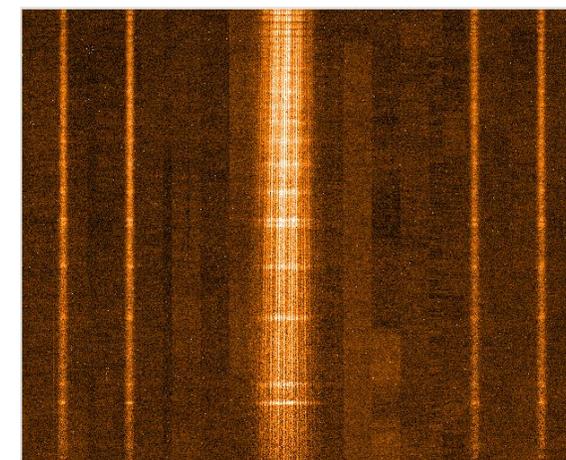
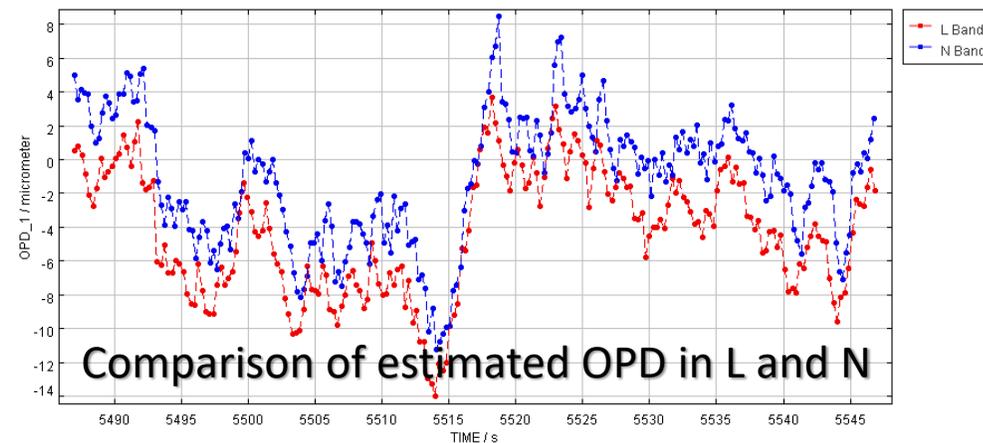


MATISSE is now ready to do science:

- First observation from the consortium on March 21
- Instrument opened to the community on April 1st

But many improvements are on their way :

- **Coherent Integration in N using L-band estimated OPD**
Coherent integration up to several minutes
Should dramatically improve N-band sensibility
- **GRAV4MAT : using Gravity-FT for MATISSE**
Increase L-band DIT beyond 1s
Especially important for L-band MR, HR, and VHR mode
- **Very-high resolution mode : R=4000**
Kinematics in Br α & CO lines 4.6-4.7





This is an happy Astronomer!



Observations should always be that way...