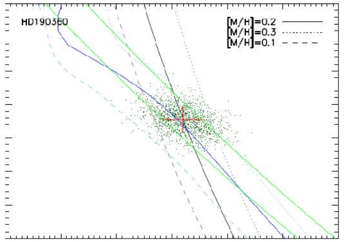
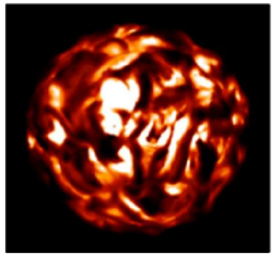
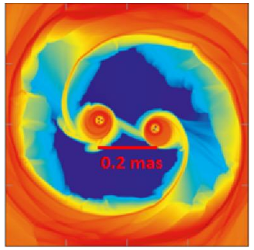
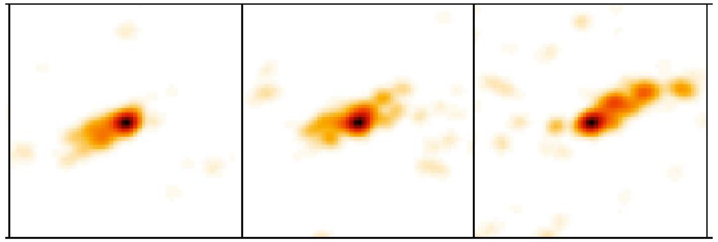


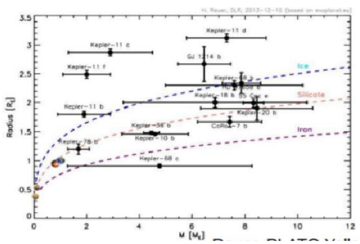




SPICA

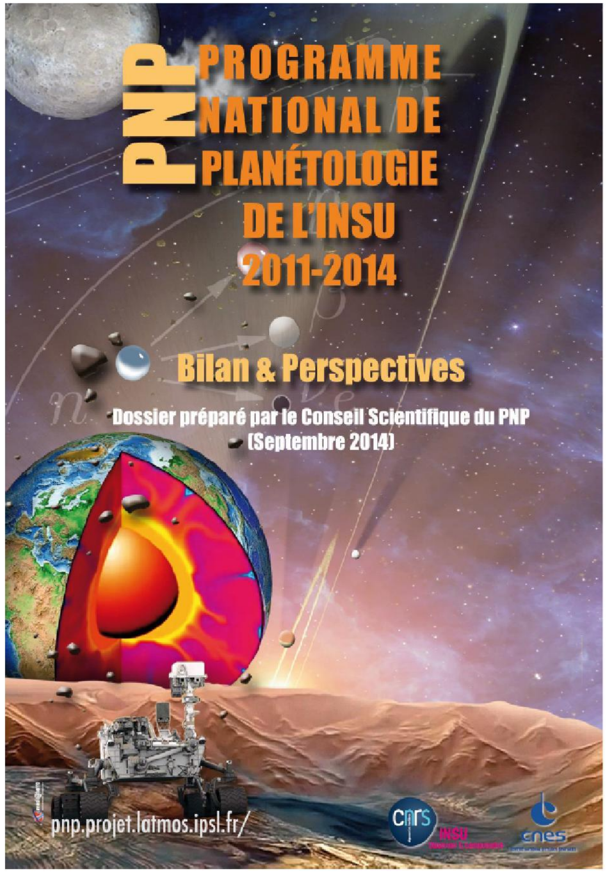
Stellar Parameters and Images with a Cophased Array





Scientific context

IF WE DON'T KNOW THE STAR, WE DON'T KNOW THE PLANETS



Exo earth
Characterization
Direct imaging
From planets to planetary systems
Planet and environment
Multiscale approach
Diversity
Formation & evolution

Stars as Sun
Star/planet
Asteroseismology
Surface imaging
Improved modeling
Habitability
Diversity
High angular resolution

The science niches of the VLT-iVis

(Millour et al., 2018, submitted to Exp. Astr.)

Fundamental parameters of MS stars

Needs: magnitude limit,
high efficiency (fast!),
many simultaneous baselines

Survey of companions of close A, B stars below 30AU (current limit of AO exploration).

Needs: limiting magnitude,
high efficiency (fast!), ≥ 4 telescopes

AGB, RSG

Needs: snapshot imaging,
(very) high spectral resolution

Stellar environments

Needs: snapshot imaging,
(very) high spectral resolution

Summary of performance

Limiting magnitude ⟶ SNR > 10 per spectral channel, in 10mn, V=0.1

Different spectral resolutions (columns) and array configurations (rows) are considered. For each spectra resolution, we consider three modes of fringe stabilization.

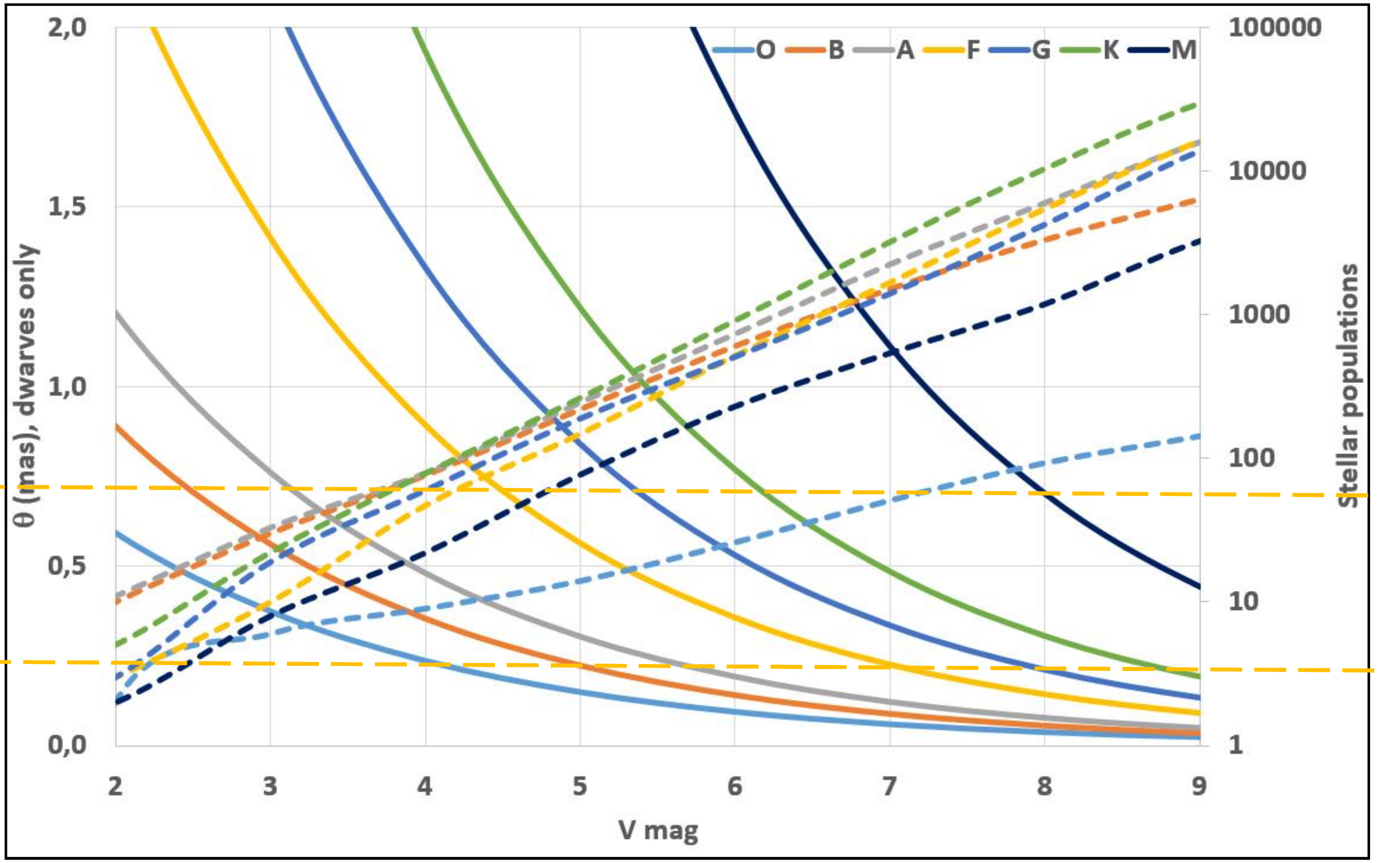
			Low Resolution			Medium Resolution			High Resolution		
Resolving power			300			3000			30000		
Width of spectral channel (nm)			2			0,2			0,02		
Number of spectral channels			150			500			500		
Total spectral band (nm)			300			100			10		
	N-V²	**N-CP**	DIT=10ms	Tracking DIT=100m	Tracking DIT=30s	DIT=10ms	Tracking DIT=100m	Tracking DIT=30s	DIT=10ms	Tracking DIT=100m	Tracking DIT=30s
4 UTs, Sr=0.08	**6**	**3**	**9.5**	**10.7**	**12.1**	**7.0**	**8.2**	**9.7**	*4.5*	**5.7**	**7.2**
4 ATs, Sr=0.3	**6**	**3**	**7.5**	**8.7**	**10.2**	*3.6*	*4.7*	**6.3**	*1.0*	*2.2*	*3.7*
6 ATs, Sr=0.3	**15**	**10**	**7.2**	**8.3**	**9.8**	*3.1*	*4.2*	**5.8**	*0.6*	*1.7*	*3.3*
8 ATS, Sr=0.3	**28**	**21**	**6.8**	**7.9**	**9.5**	*2.8*	*4.0*	**5.5**	*0.3*	*1.5*	*3*

SNR=10(/Ch) V*=0.1, Tint=10mn

Statistics of the CHARA sky

θ>0.7mas

θ>0.2mas



	O	B	A	F	G	K	M
Limiting magnitude for θ>0.2mas	4.3	5.2	5.9	7.2	8.2	8.8	10.6
Number of stars with θ>0.2mas	10	266	646	2128	5420	23904	8377
Limiting magnitude for θ>0.7mas	1.5	2.5	3.3	4.5	5.4	6.2	8.0
Number of stars with θ>0.7mas	0	19	40	86	277	1153	1168

High level requirements

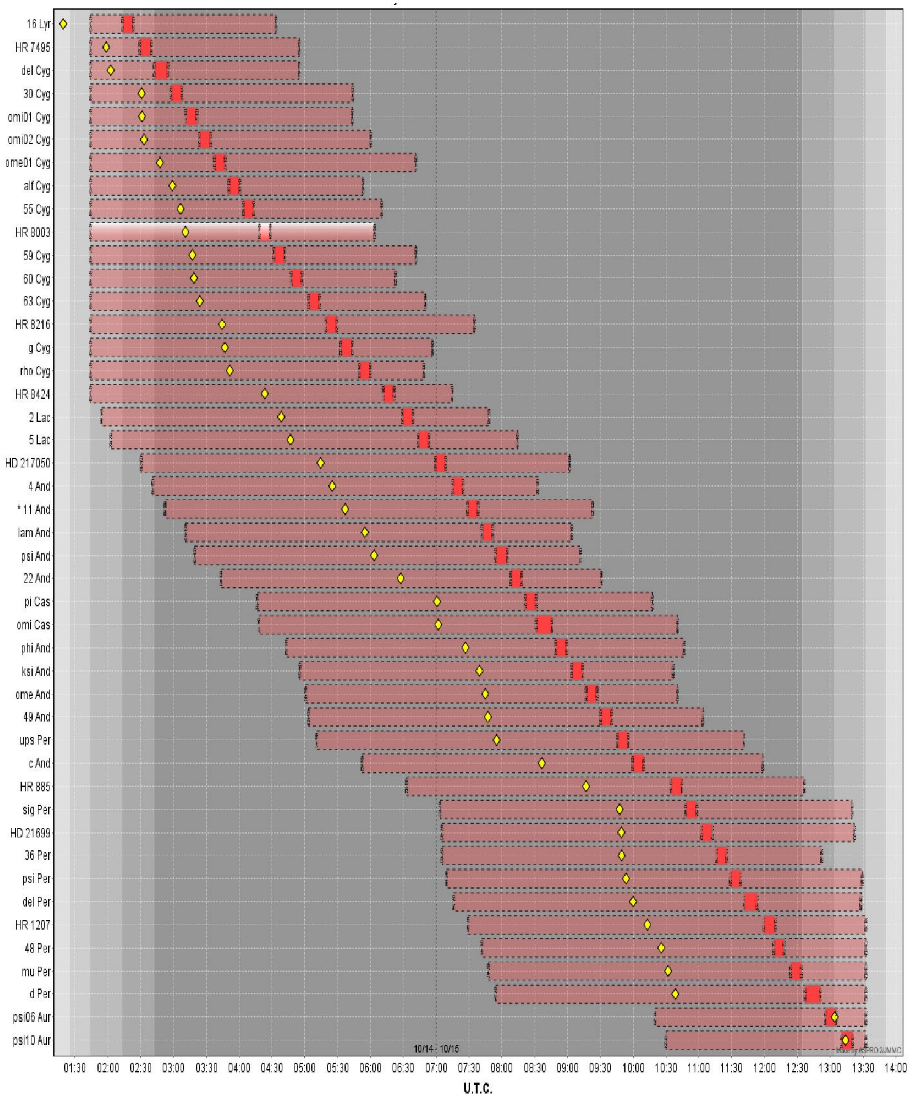
Diameters:

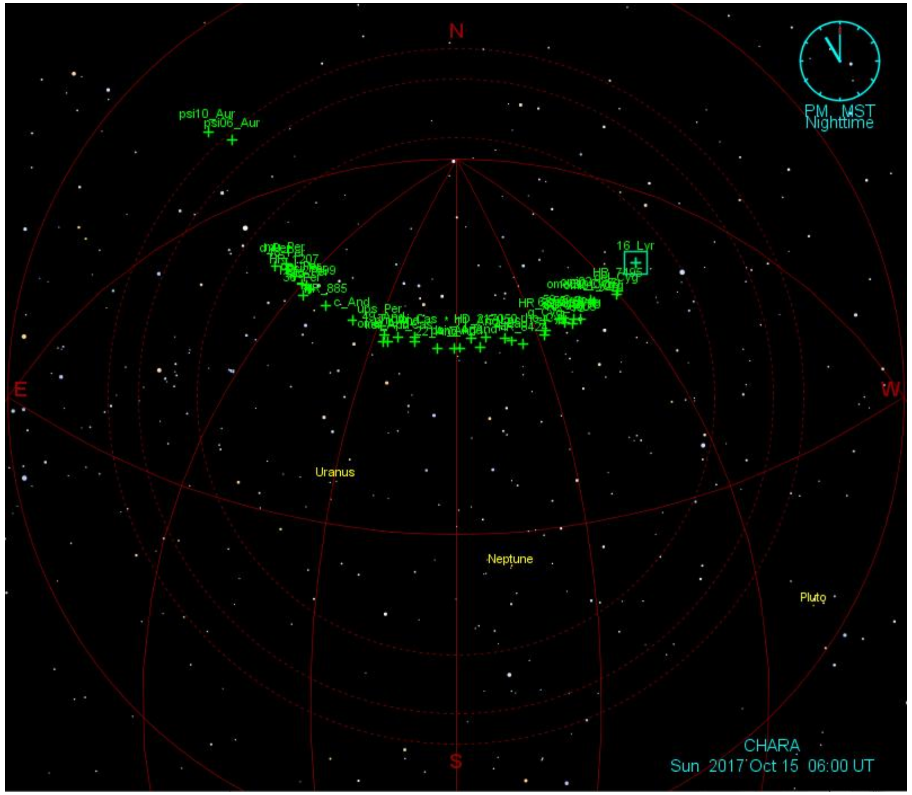
- magR=6 (but at low V^2)
- High precision, high efficiency (6T)
- R=300 (LR mode)

Imaging

- magR=4 (but at low V^2)
- UV coverage (6T, +Supersynthesis)
- R=3000 (MR mode)

Survey mode testing with VEGA+CLIMB 2017-10-15



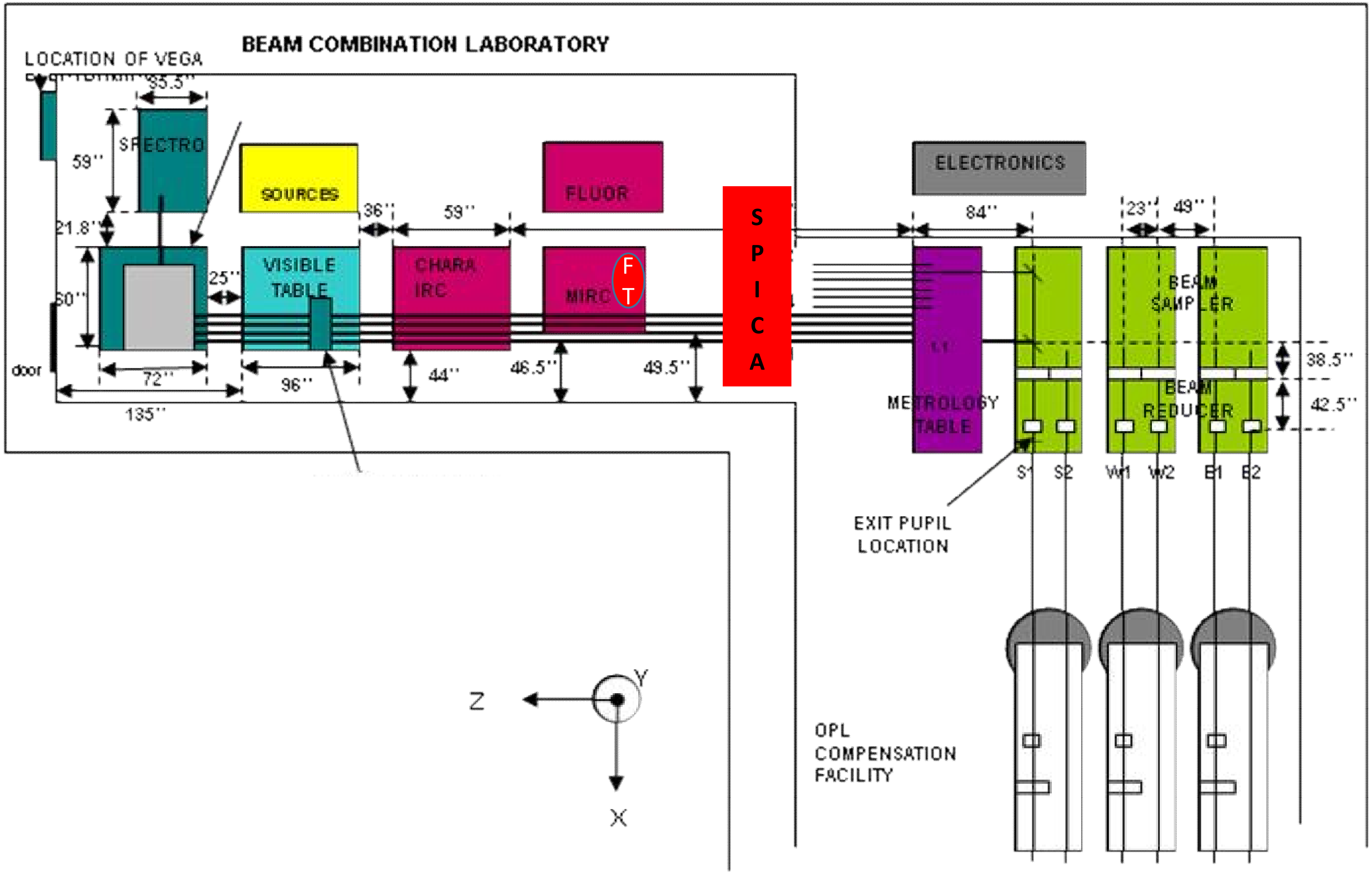


10mn per star, every 15mn. Clear identification of overheads (actions in progress)

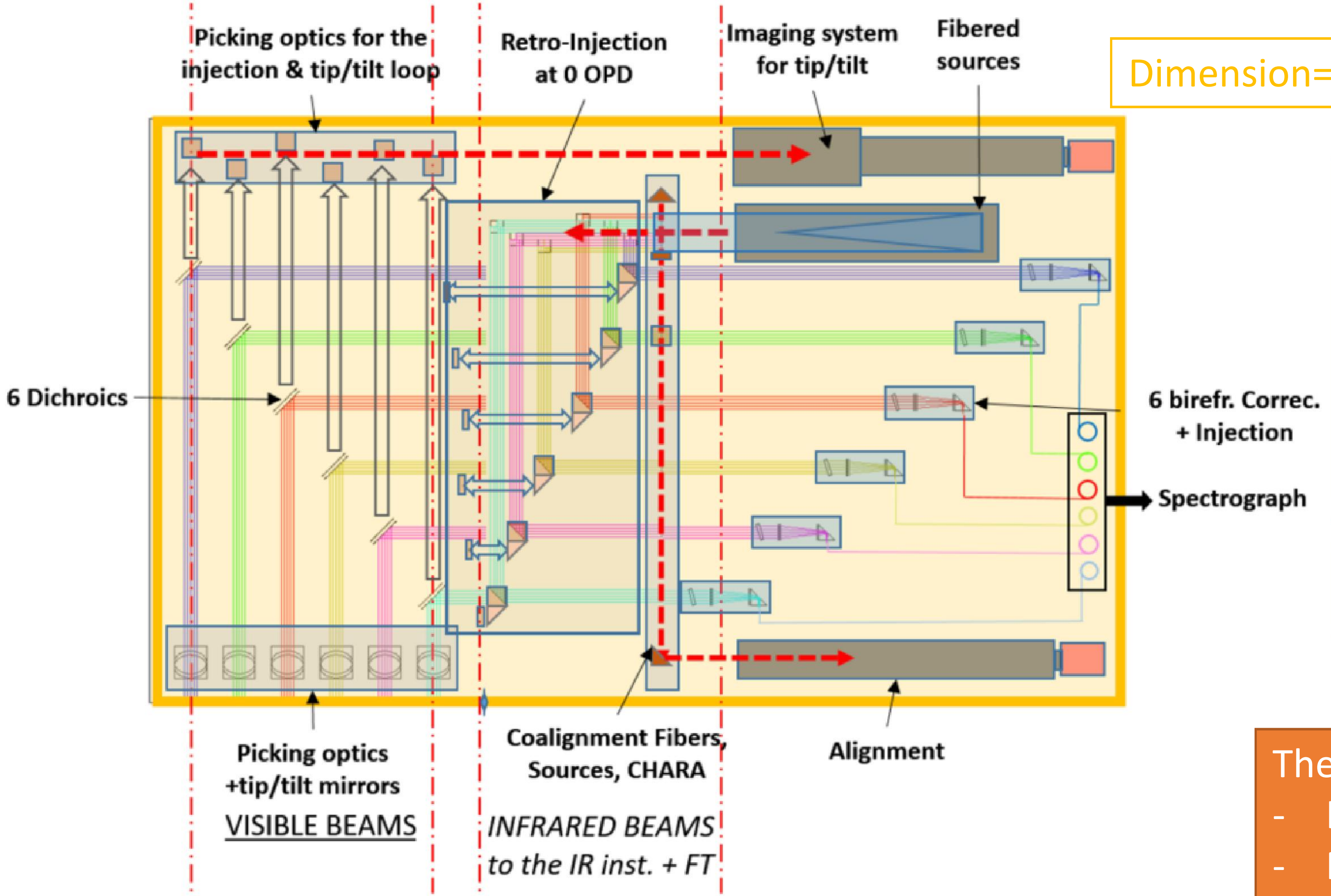
Night=115Gb ⇔ SPICA~1Tb…

No fringes drift, no pupil drifts. Only 1 NIRO alignment after a crash

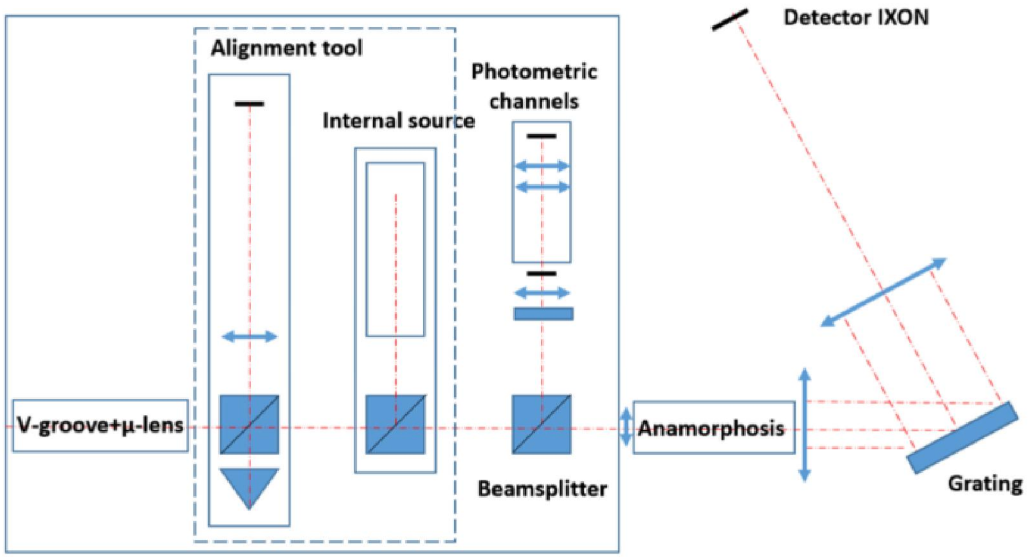
Data processing in progress ➔ stability of the transfer function?


BEAM COMBINATION LABORATORY
LOCATION OF VEGA
35.5''
59''
SPECTRO
SOURCES
FLUOR
ELECTRONICS
21.8''
36''
59''
84''
23''
49''
VISIBLE TABLE
CHARA IRC
MIRC
F
T
S
P
I
C
A
25''
60''
BEAM SAMPLER
door
72''
96''
44''
46.5''
49.5''
38.5''
42.5''
135''
METROLOGY TABLE
BEAM REDUCER
S1
S2
W1
W2
E1
E2
EXIT PUPIL LOCATION
OPL COMPENSATION FACILITY
Z
Y
X

Optical design of SPICA

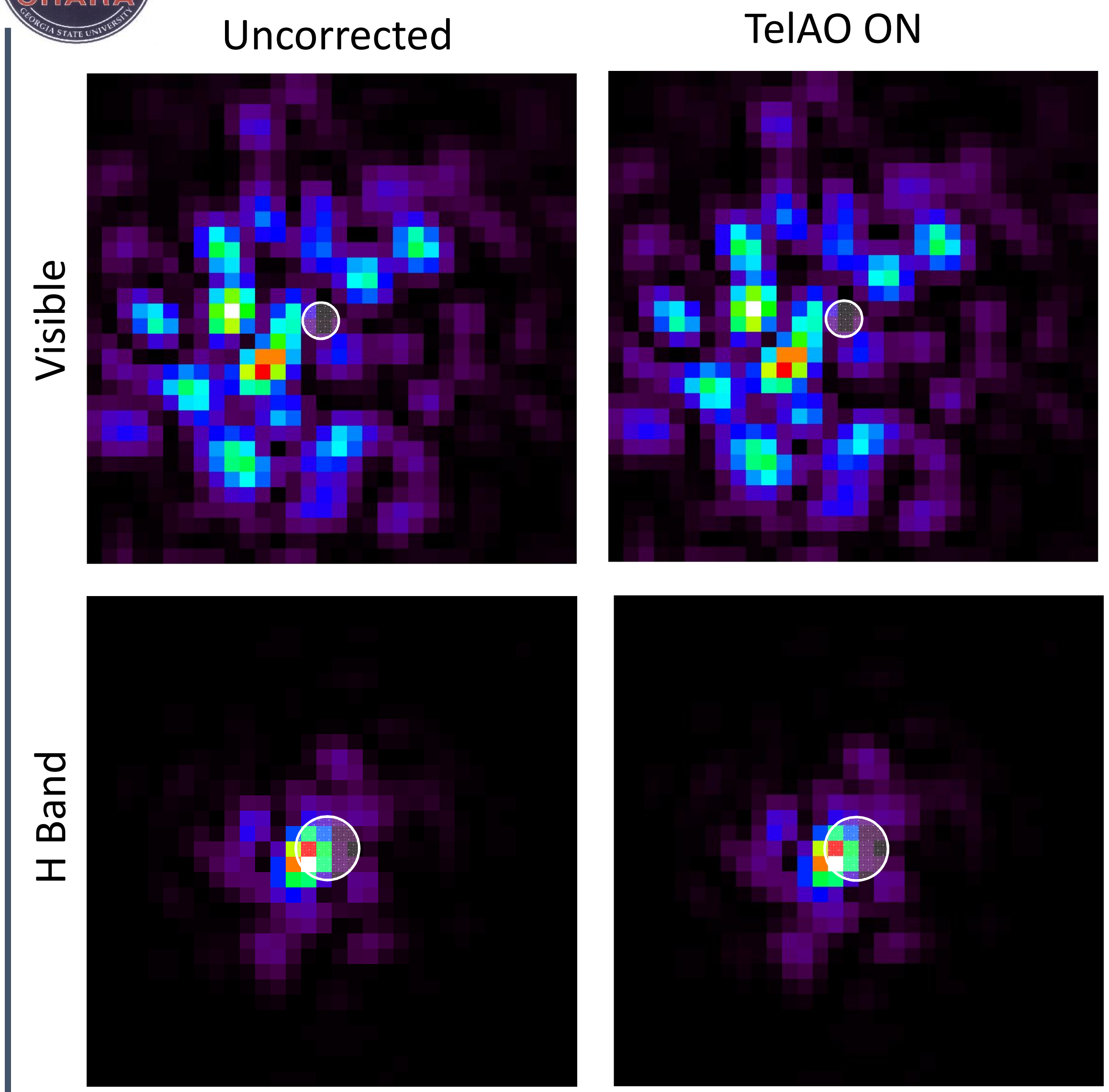


Dimension=(3'x5')



The two main difficulties are:

- Injection in SM fibres in partial AO correction
- Phase tracker for long exposure capabilities



Qualitative behaviour under partial correction by AO
Based on the code by Mike Ireland
~r0=10cm, t0=6ms

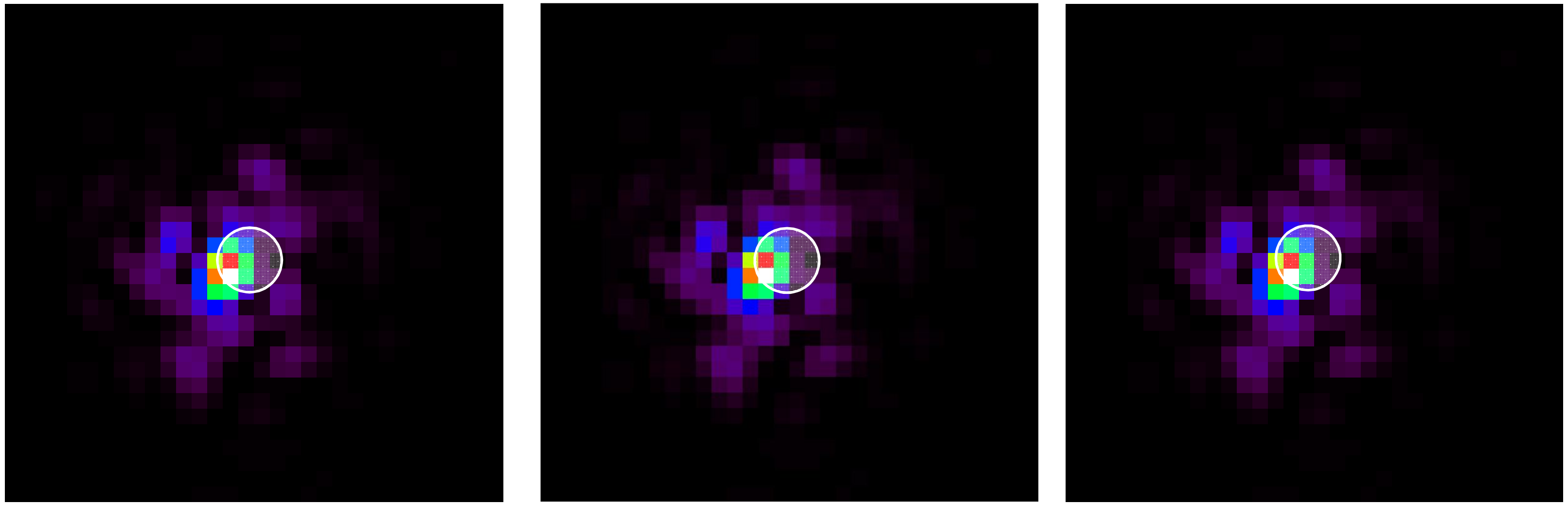
More quantitative analysis by M.A. Martinod (2018)

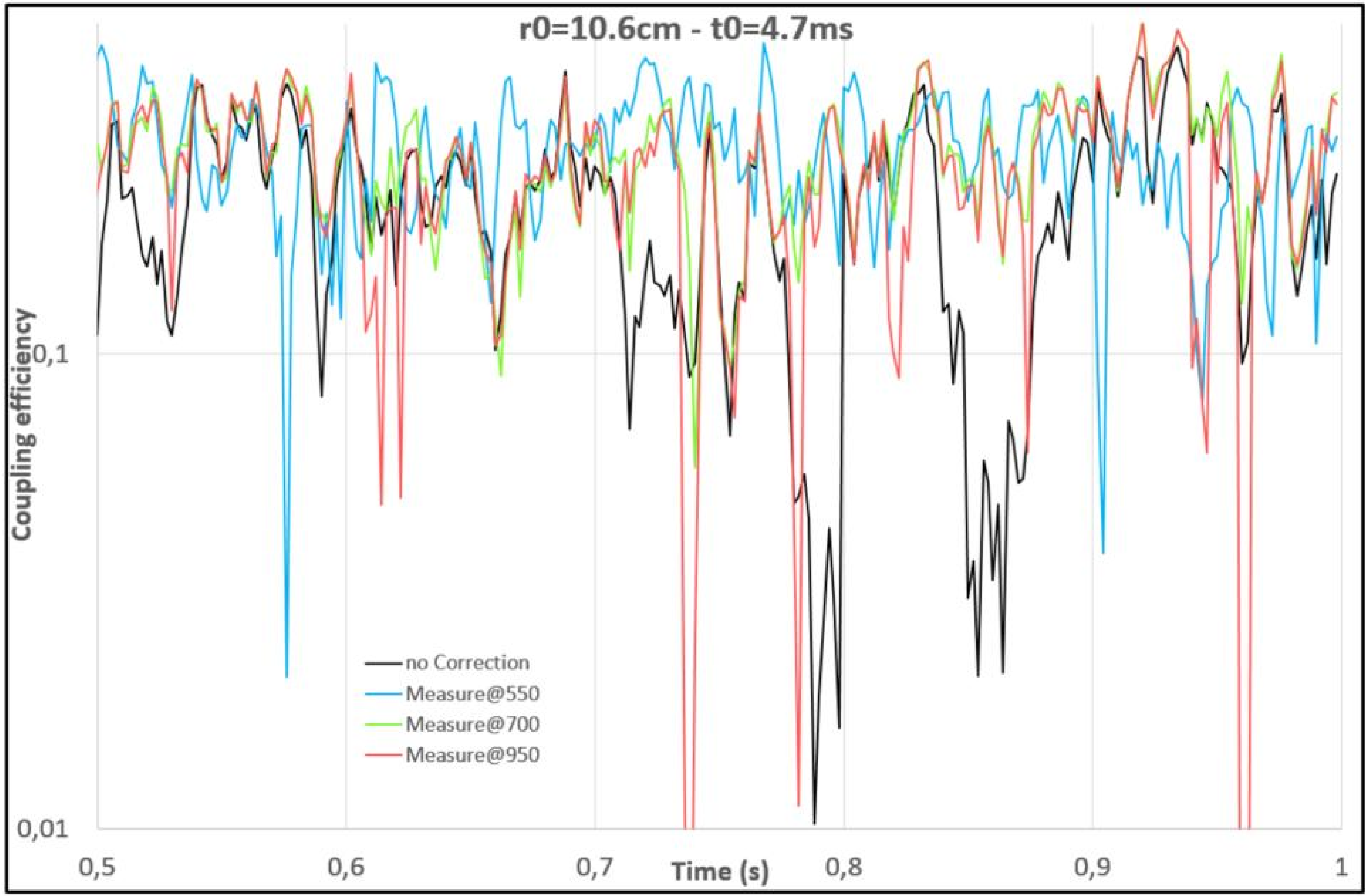
Uncorrected | TelAO ON | TelAO ON + T/T

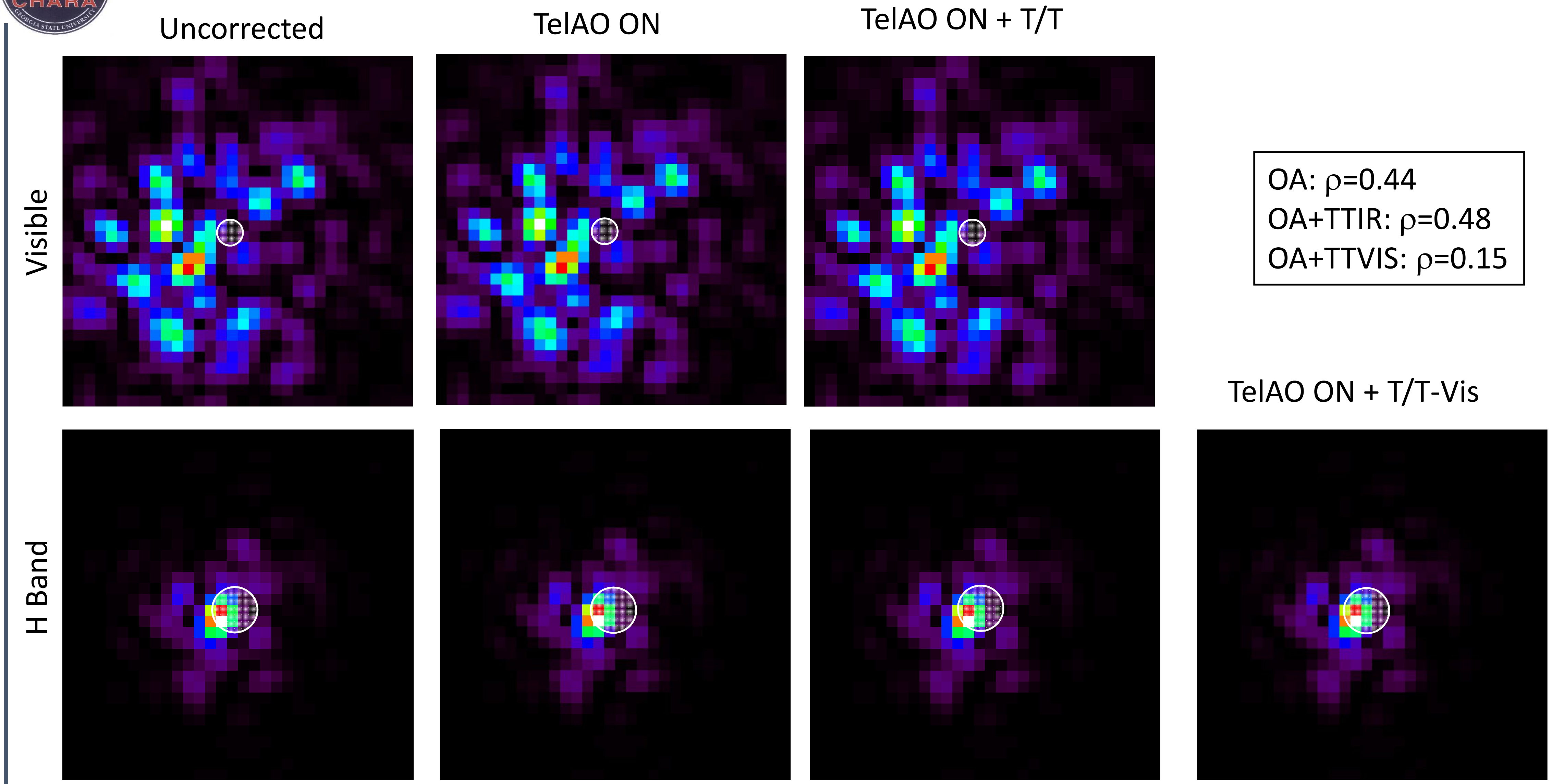
r_0 (cm)	$<\rho>$ sans OA (%)	$<\rho>$ sans TT (%)	$<\rho>$ avec TT (%)
6	0.5 ± 0.4	1.37 ± 1.37	2.16 ± 1.85
10	1.3 ± 1.6	11.4 ± 7.49	16.5 ± 6.51
12	1.8 ± 2.2	21.4 ± 7.04	25.6 ± 5.9

M.A. Martinod, 2018 in progress

H Band

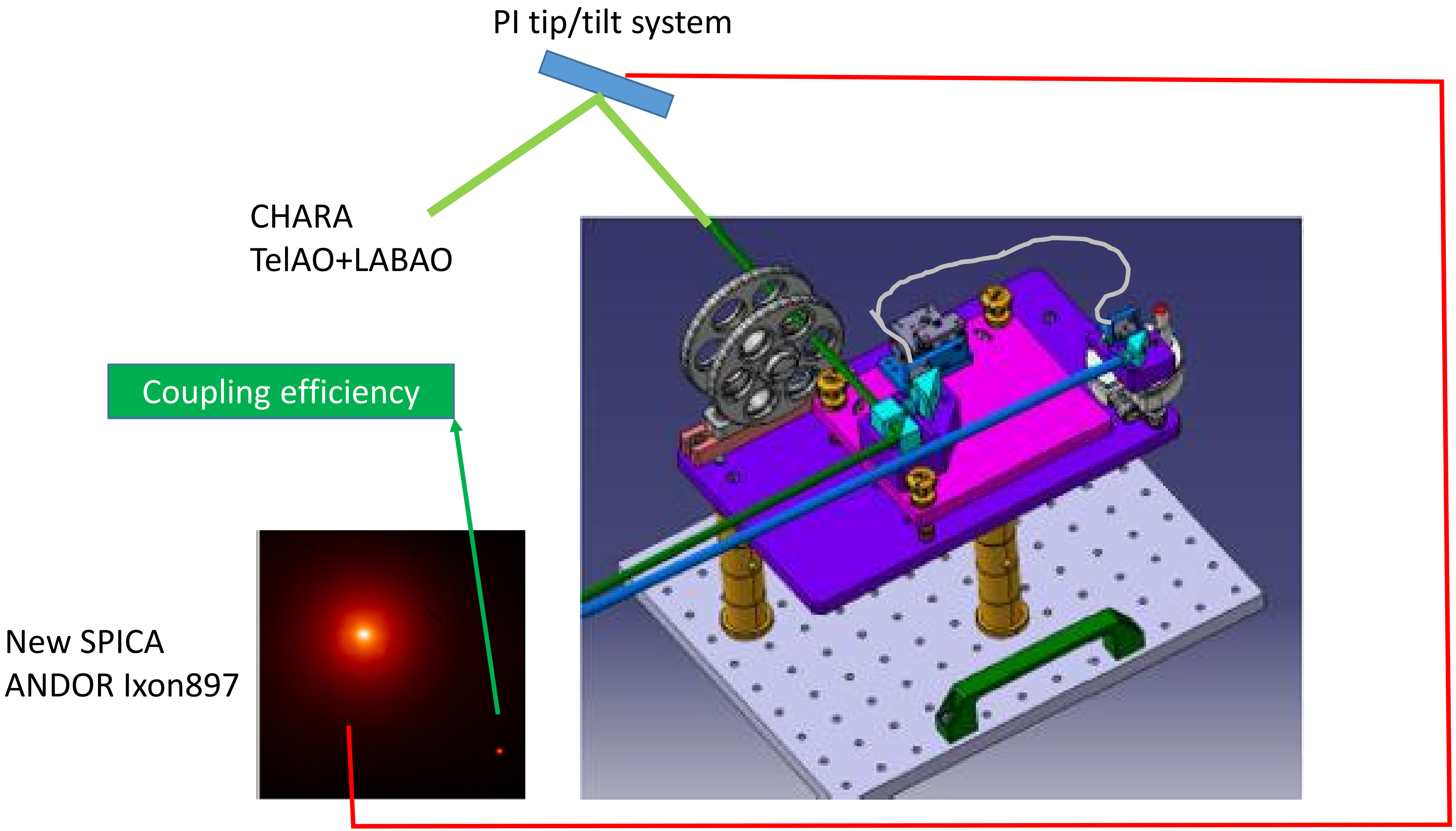



r0=10.6cm - t0=4.7ms
Coupling efficiency
0,1
0,01
0,5
0,6
0,7
0,8
0,9
1
Time (s)
no Correction
Measure@550
Measure@700
Measure@950



OA: ρ=0.44
OA+TTIR: ρ=0.48
OA+TTVIS: ρ=0.15

Design of the CESAR experiment



SNR consideration … long exposures ➔ Fringe Tracker

Limiting magnitude defined as S/N=10 per spectral channel in 10mn of integration

	R=140	R=3000
V^2=0.25	8.7	5.4
V^2=0.01	5.5	2.3

Table 1: Limiting magnitude with a group delay tracker only

	R=140	R=3000
V^2=0.25, DIT=0.2s	10.1	6.7
V^2=0.01, DIT=0.2s	6.7	3.5
V^2=0.25, DIT=30s	10.4	7.1
V^2=0.01, DIT=30s	7.0	4.0

Degraded transfer function (DIT=30s rows)

Table 2: Limiting magnitude with a phase tracker

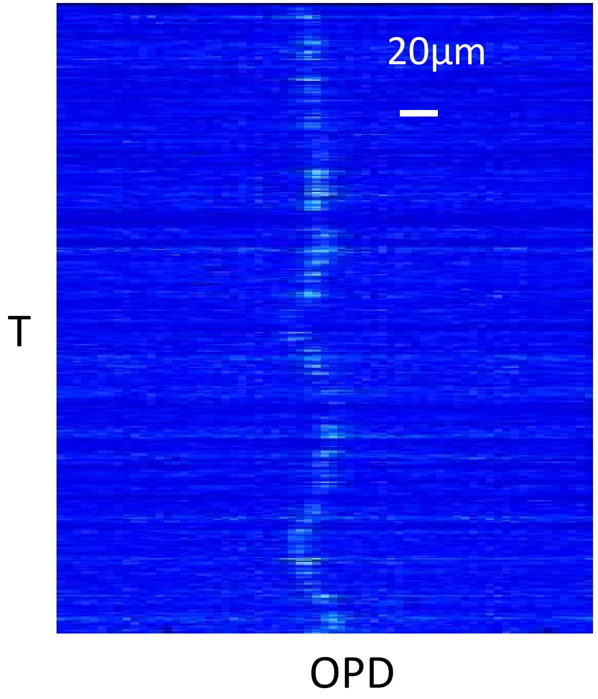
These estimations use the same S/N calculator of FRIEND, validated on-sky

SPICA/CHARA FT: guiding principles and baseline solution

- Do not re-invent the wheel: lessons learned from CHAMP, GRAVITY-FT
- Minimization of the development
- Full integration inside the CHARA infrastructure: a general-purpose FT if possible

- ➢ ABCD all pairs
- ➢ IO device, H band Silicium technology
- ➢ Fast and low noise detector

FRIEND Oct. 2015



The solution:
- Use the H-band MIRCx fibres to feed a 6T ABCD IO component that will feed the MIRCx Selex detector
- Develop a real-time phase sensor software + a state machine to control the CHARA DL

IO component for 6T-ABCD fringe sensor

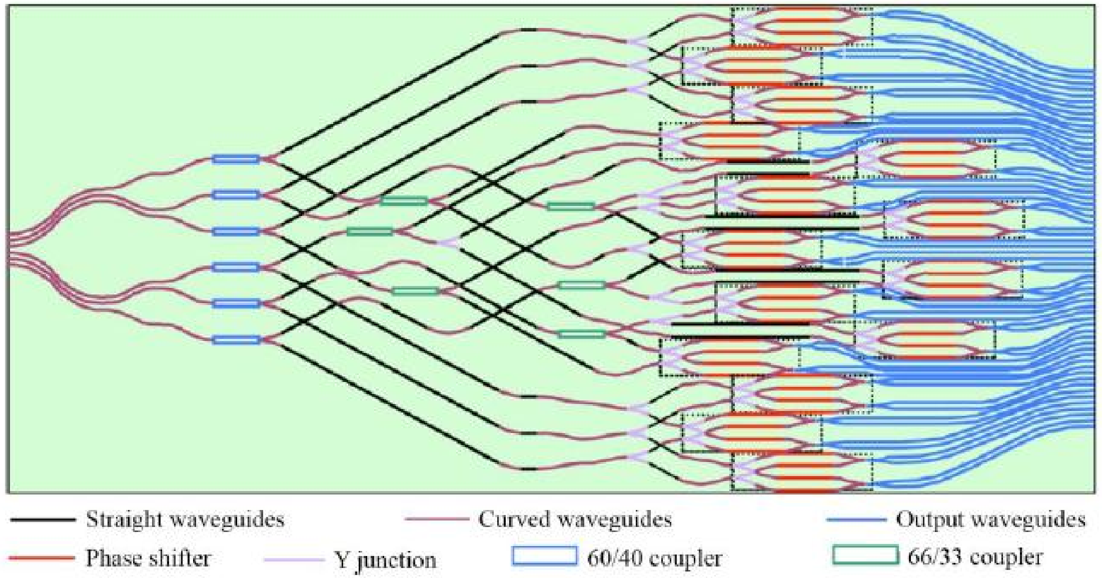


Fig. 1. Scheme of a 6-telescope beam combiner. For clarity, this scheme is vertically anamorphozed by a factor 2. From Labeye PhD, 2008.

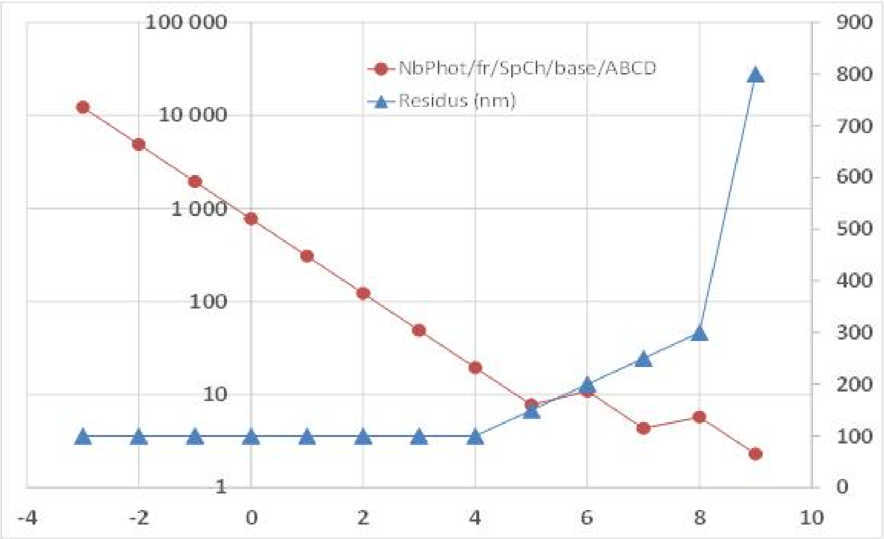
Pre-study made by VLC photonics

- *Technology is mature (2 or 3 different platforms)*
- *T between 35% and 50% (+?)*
- *Cost: 13k€ + 30k€ - 3-4m delay*

The specifications are the following:

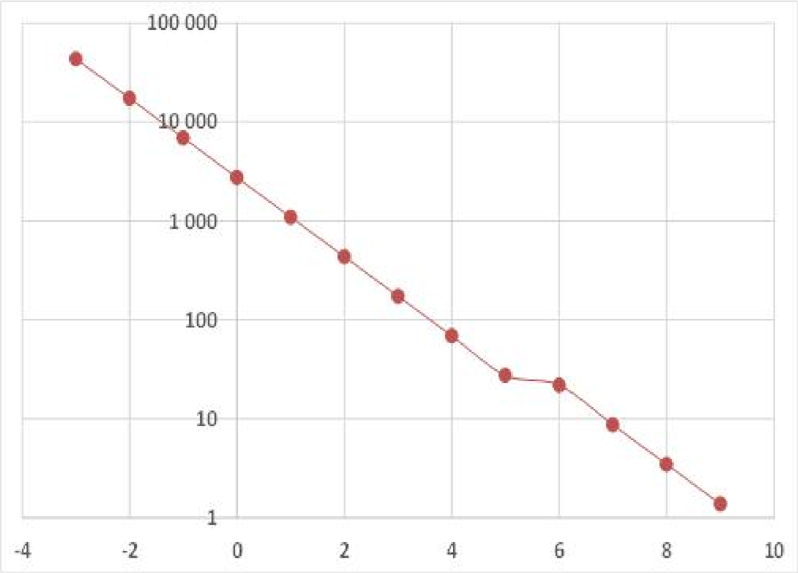
- Operation wavelength range: 1.5-1.8 µm (i.e., H astronomical band)
- Single-mode waveguides over the H band and with a Numerical Aperture (NA) in agreement with the standard NA of single-mode fibers: NA at $1/e^2$: 0.13 < NA < 0.15 at 1.55 µm in all directions
- Operation with both linear polarizations simultaneously
- Number of telescopes to be combined: 6
- Number of baselines to be coded: 15
- Type of fringe coding: ABCD coding
- Phase shift between 4 ABCD outputs: 90° +/- 10° over the whole spectral band.
- **Throughput: larger than 60% over the H band (goal: 65%)**
- Contrast level: larger than 95% in polarized light
- Flux balancing: all the outputs corresponding to one input waveguide should have the same flux over the H band. Tolerance: +/- 15%
- Flux cross-talk: below 0.5% (an input beam that is not supposed to contribute to a fringe pattern contribute to less than 0.5% of the flux)

Estimation of performance for a H-band CHARA FT



VLTI-GRAVITY FT performance

H band FT, 5 SpCh, 6T ABCD, Selex detector. T0=10ms , Texp=5/10ms



SPICA Development Plan

Fringe Tracker

- Funding application (CNRS) for FT sent on 1 Mar 2018 (→ June 2018)
- Design phase of the IO component (Summer 2018) + construction (this fall)
- Photometric characterization at IPAG (winter 2018)
- Construction of the FT 6T testbench in Nice (beg. 2019) on the basis of the LESIA Gravity-FT table extended to 6 beams
- Development of the control system, phase sensor, state machine in 2019 (based on the Gravity software)
- Acceptance for departure to CHARA: Spring 2020
- Integration: Summer 2020

- 2-year postdoc funded by OPTICON (Fabien Patru, this fall)
- Support from Lagrange Lab in Nice for opto-mechanical interface to MIRCx

SPICA

- CESAR to CHARA in June 2018. Final validation of the optical design (including or not TT mirror, sensor for TT)
- Funding application (ANR) in Nov. 2018
- Start of the detailed design by the Nice technical group (after the final delivery of MATISSE): end of 2018.
- Construction in Nice from Summer 2019 to Summer 2020. Tests in Nice winter 2020
- Integration at Mount Wilson around Summer 2021

PDR: T4-2018

FDR: T2-T3 2019

Look for alternative funding solutions at University level (end of 2018) or EU level in 2019.