Update on the developments of CHARA/SPICA

D. Mourard and the VEGA/SPICA team

P. Bério, N. Nardetto, F. Allouche, C. Bailet, J. Dejonghe, S. Lagarde,

D. Lecron, A. Meilland, F. Morand, F. Patru, S. Rousseau

+MIRCx/MYSTIC team

+ CHARA team

Rapid news about VEGA

2018	nights	closed	poor	ok
FEB	10	6	2	2
APR	10	4	0	6
JUL	10	0	0	10
AUG	7	2	0	5
OCT	10	4	5	1
DEC	6	1	3	2
TOT	**53**	**17**	**10**	**26**
		32%	**19%**	**49%**

+ already 14n in 2019 >70% closed…

3 publications in 2018

P38: "Physical properties of β Lyrae A and its opaque accretion disk", **D. Mourard**, M. Broz, J. Nemravova et al.
P37: "The GJ504 system revisited: Combining interferometric, radial velocity, and high contrast imaging data", **M. Bonnefoy**, K. Perraut, A.M. Lagrange et al
P36: "Accurate effective temperatures of the metal-poor benchmark stars\par HD140283, HD122563, and HD103095 from CHARA interferometry", **I. Karovicova**, T. White, T. Nordlander et al.,

Most advanced studies ➔ publication 2019

Borgniet et al. HD113337, expn host star (VEGA data + LBTI + Herschell ➔ submitted in a few days)
Saldanha et al., omi Aqr, Be star + preparation of the analysis of the large survey
Nardetto et al., SBC of late type stars
Perraut et al., end of the ro Ap program
Ligi et al., HD219134 exopn host star

+ work in progress: cepheids, β Lyrae II, nova …

Important software upgrades in the direction of CHARA/SPICA

- Simplification of the procedure for the preparation: everything is done in ASPRO2. Tests of A2P2 (direct link between ASPRO2 and Cosmic Debris)
- Full communication between CD and VEGA during obs through VEGA Server
- Corrections of many issues but no longer developments
- High level VEGA SPY status

Progress on CHARA/SPICA

SPICA is build on the combination of the new AO systems, single mode fibres for spatial filtering, and modern EMCCD detectors.
It will operated in LR (R=300) and MR (R=3000) dispersed fringes of 6T (15 baselines).
It is assisted by a H-band fringe tracking system.

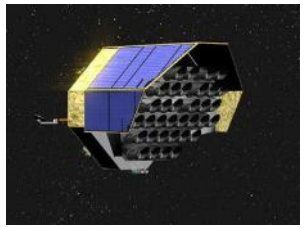
As such, SPICA has many science goals but the top level requirements are given by the idea of a large survey of stellar fundamental parameters.

SPICA activities are divided in three main groups:

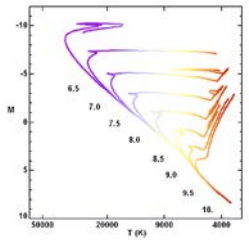
1. Science group
2. SPICA-FT
3. SPICA-VIS

Atmosphere models
(T_{eff}, log(g), Z, v_t)

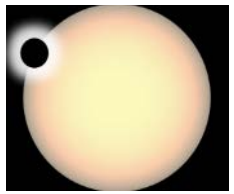
θ cal
V^2(cal) V^2 (sci, brut)
Transfert function (strategy)
LD Law
θ_{UD} (sci)
θ_{LD} (sci)
Phase 1: 1000 bright stars (mv<8)
Phase 2: PLATO follow-up



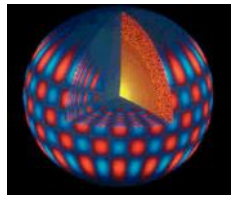
Stellar Activity
Spots
Granulation
Wind/Environment
Rotation
Multiplicity



Evolution Atmosphere Models Binarity | π Gaia | **Stellar activity**
$age_\star$ $R_\star$ $M_\star$ $T_{eff,\star}$
Transits $\rho_\star$ | RV
R_p M_p
ρ_p
Objective 1 : Life Habitable Zone | **Model of Planets**



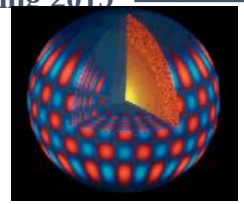
Evolution Atmosphere Models Binarity | **Scaling relations** | π Gaia | **Stellar activity**
$age_\star$ $R_\star$ $M_\star$ $T_{eff,\star}$
Objective 2: Fundamental parameters



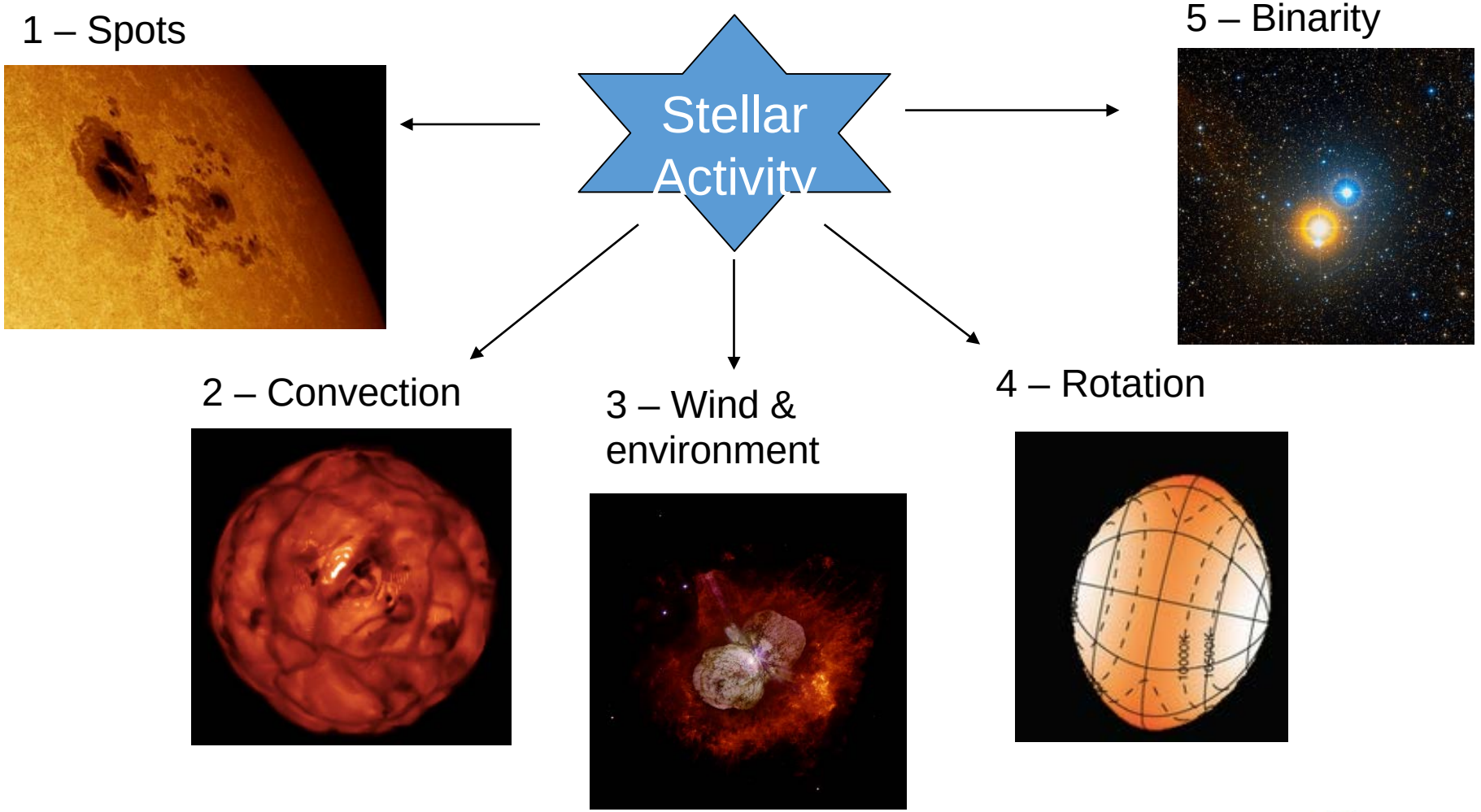
Evolution Atmosphere Models Binarity | **SED Analysis Diagnostic of activity** | **Homogeneous Photometry**
$age_\star$ $R_\star$ $M_\star$ $T_{eff,\star}$
Objective 3a: Surface-Brightness Color Relations (SBCR) for all types and classes corrected from stellar activity
Tool for faint stars observed by PLATO (phase 2)
Objective 3b: Distance scale Ho

Three objectives:

1. Exoplanet Host Stars
2. Asteroseismology
3. SBCR for distances of EB and PLATO


For these three objectives, stellar activity has to be taken into account:



CHARA/SPICA phase 1 (2021=>2024): 800* standards (diameters) + 200* actives (images)

III

IV

V

WP8: ~100* Binaries (including EBs) => M => Evolution models => PLATO/WP121

WP6: ~30* O, B1, B2, B3 to be characterized:

. SBCR : distance of EB (M31/M33)

. wind, multiplicity, rotation expected

WP4: 380* standard stars B4-F5 V/IV/III in order to fullfil the statistics of JMDC
Including asteroseismic targets such as beta-Cephei stars, SPB, roAp
(WP7: Comparison SBCR I—V/III)

WP3: ~200* known asteroseismic targets F5/K7-III
CoRoT, SONG, TESS
P2:PLATO bright stars => complementary science

If active (mostly convection, environnent, spots): characterization/images

If not active: SBCR (III)

WP2: ~200* known asteroseismic targets F5/K7-IV/V
CoRoT, SONG, TESS
P2:PLATO bright stars => WP122

If active (rotation >50km/s, spots): characterization/images
Spots=> comparison
Doppler Imaging

If not active: SBCR (IV/V)

WP7: Comparison: empirical + theoretical (based on different atmosphere models)
P2: PLATO/WP122
(faint stars mV>8)

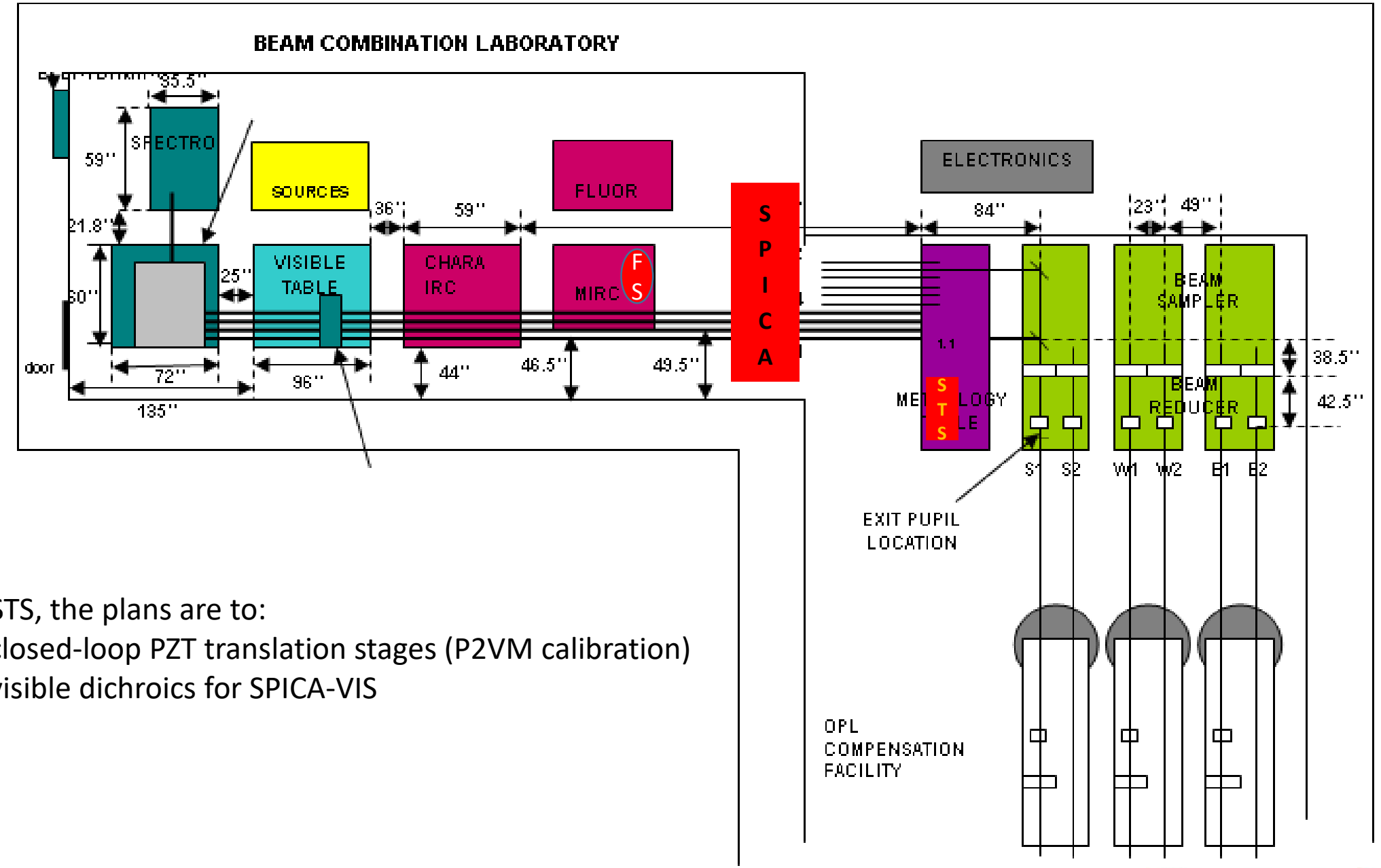
WP1: ~20* known Exoplanet host stars => R* => Rp => P2:PLATO/WP122

WP9: ~20* Rotating stars for gravity darkening (SPICA+MIRC-X)

WP10: ~20* YSO => planet formation

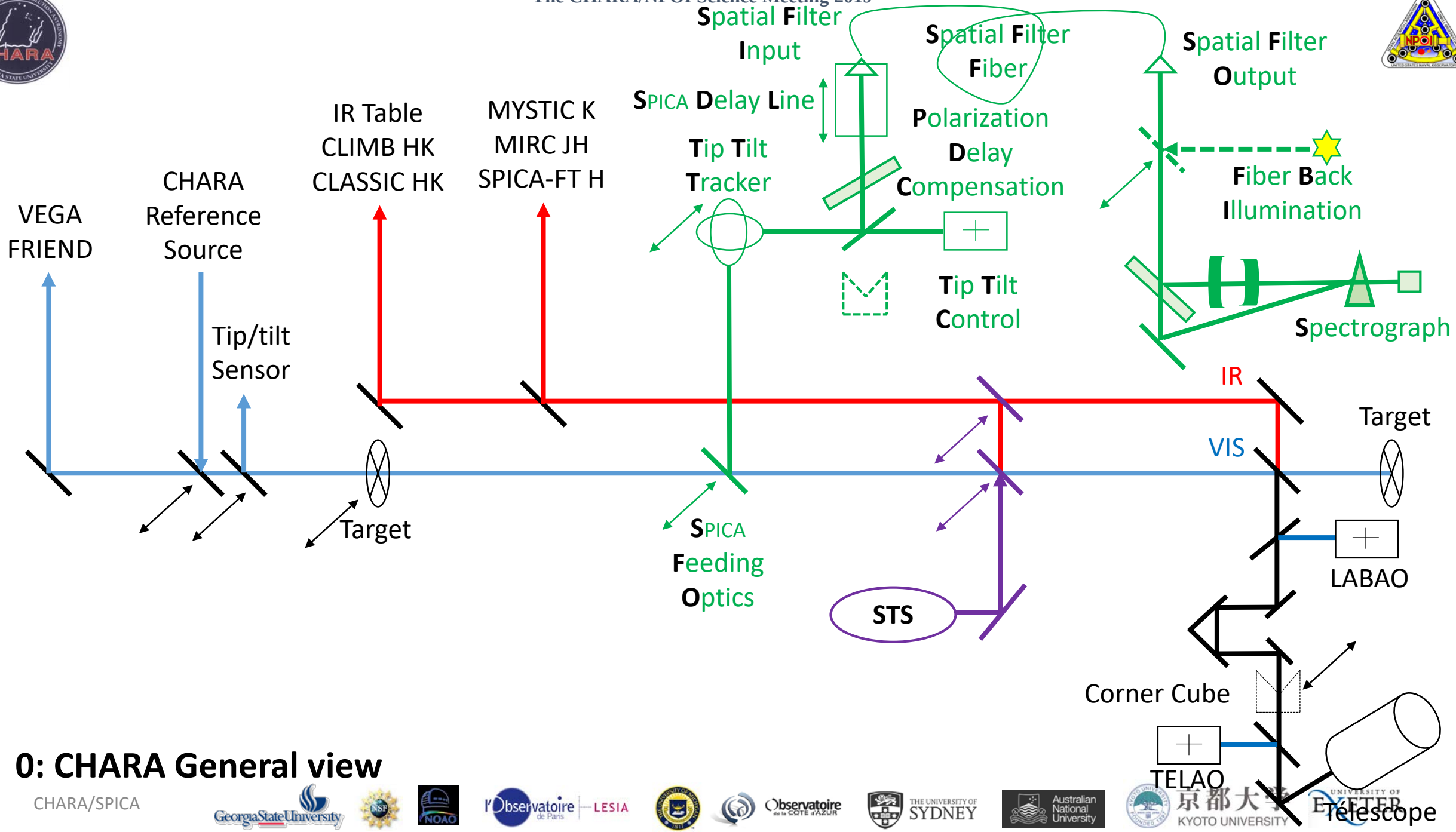
WP5: 20* MV to be characterized:
.SBCR for P2:PLATO (faint stars)
.Stellar Evolution models
.Wind/environment expected

CHARA/SPICA O B A F G K M



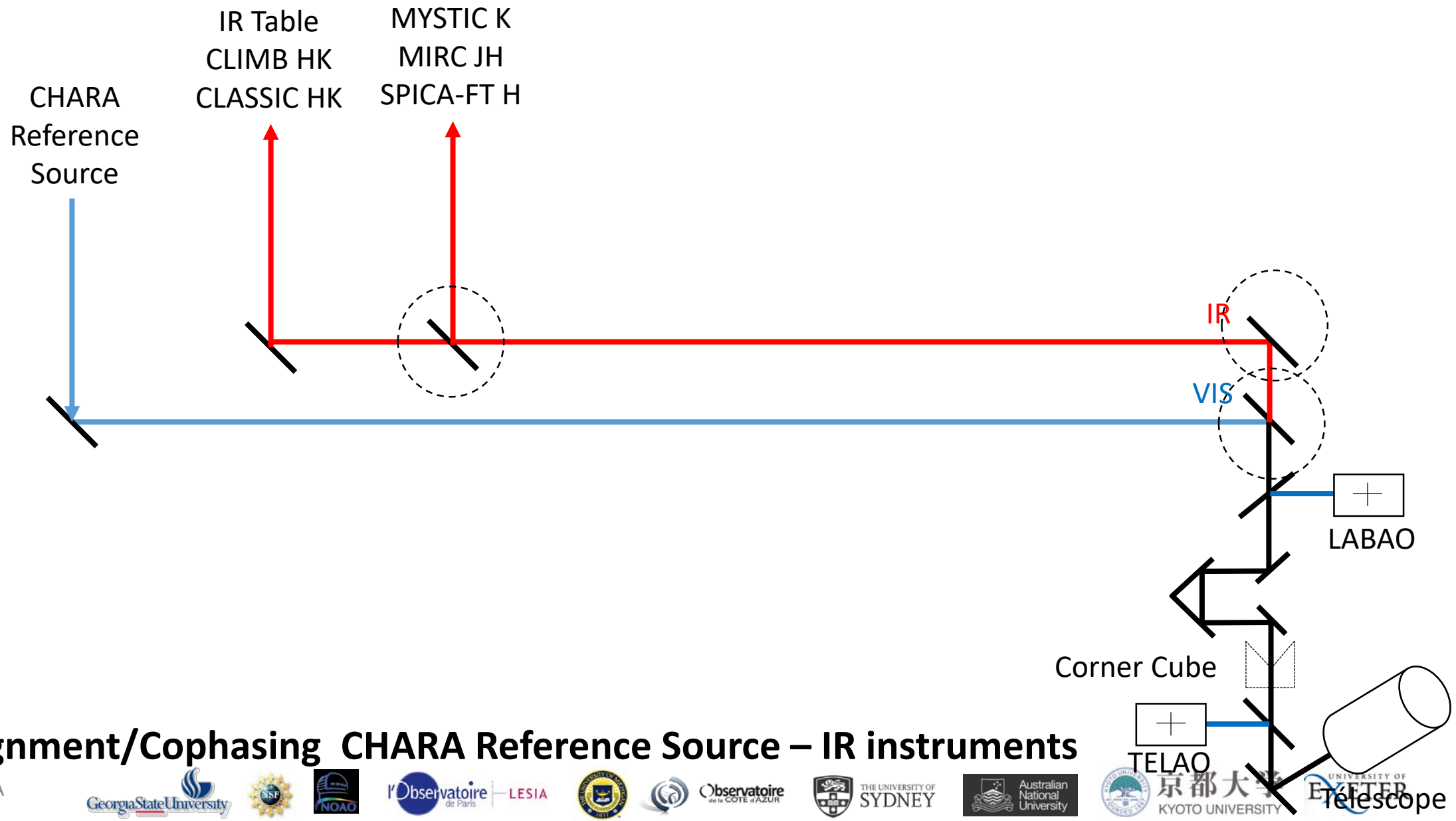
For the STS, the plans are to:

- Add closed-loop PZT translation stages (P2VM calibration)
- Add visible dichroics for SPICA-VIS

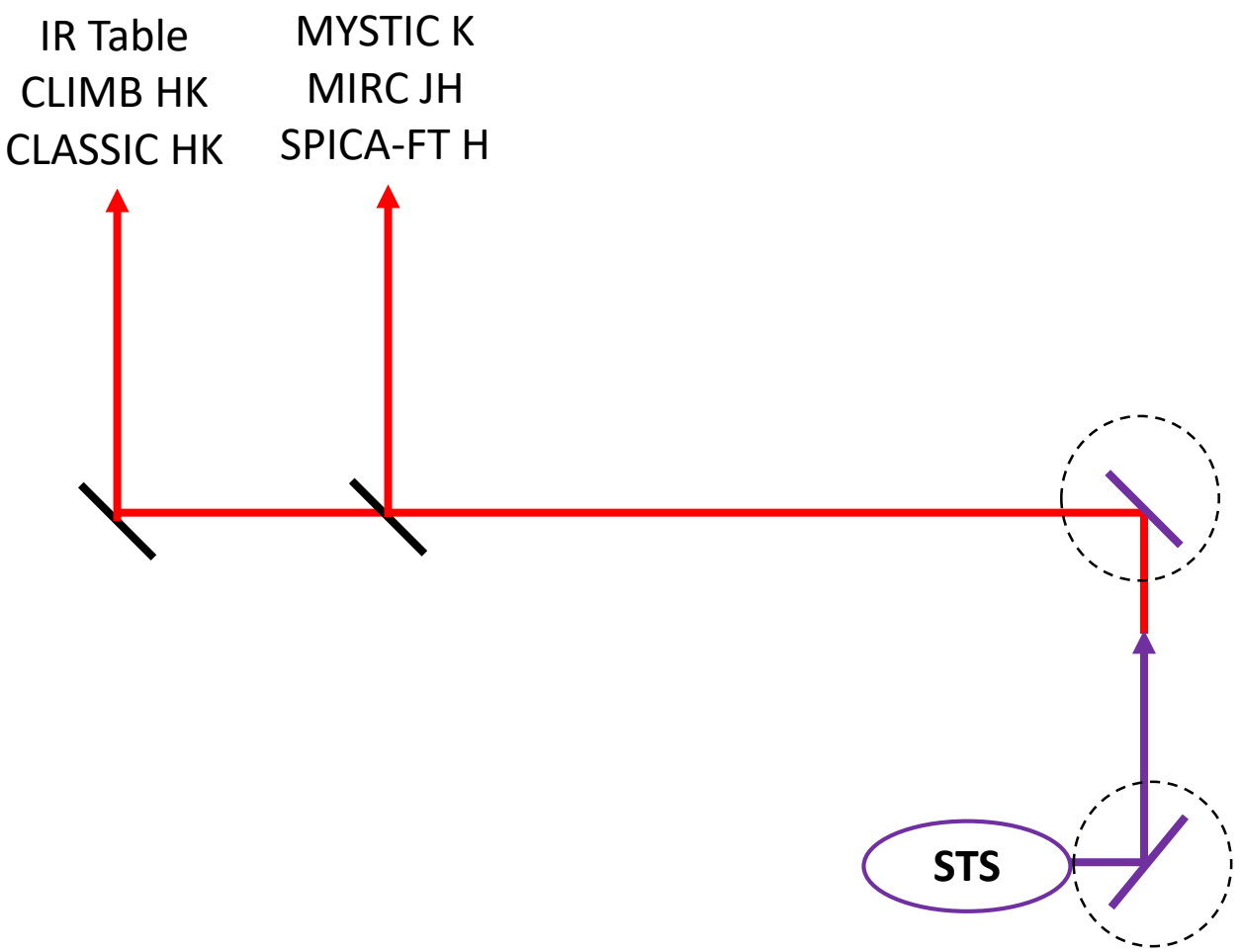


0: CHARA General view

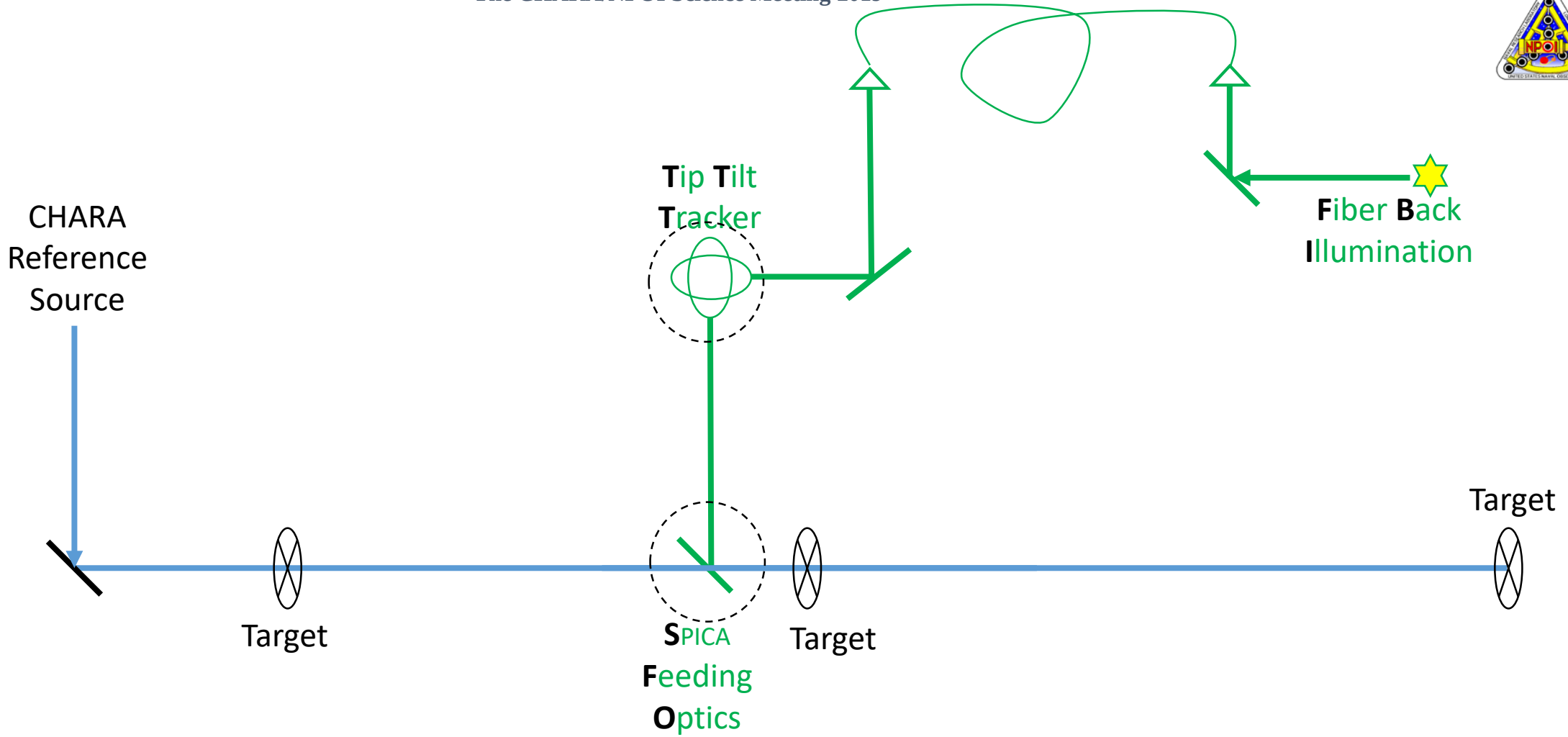
1: Alignment CHARA Reference Source (CHARA Reference Axis)



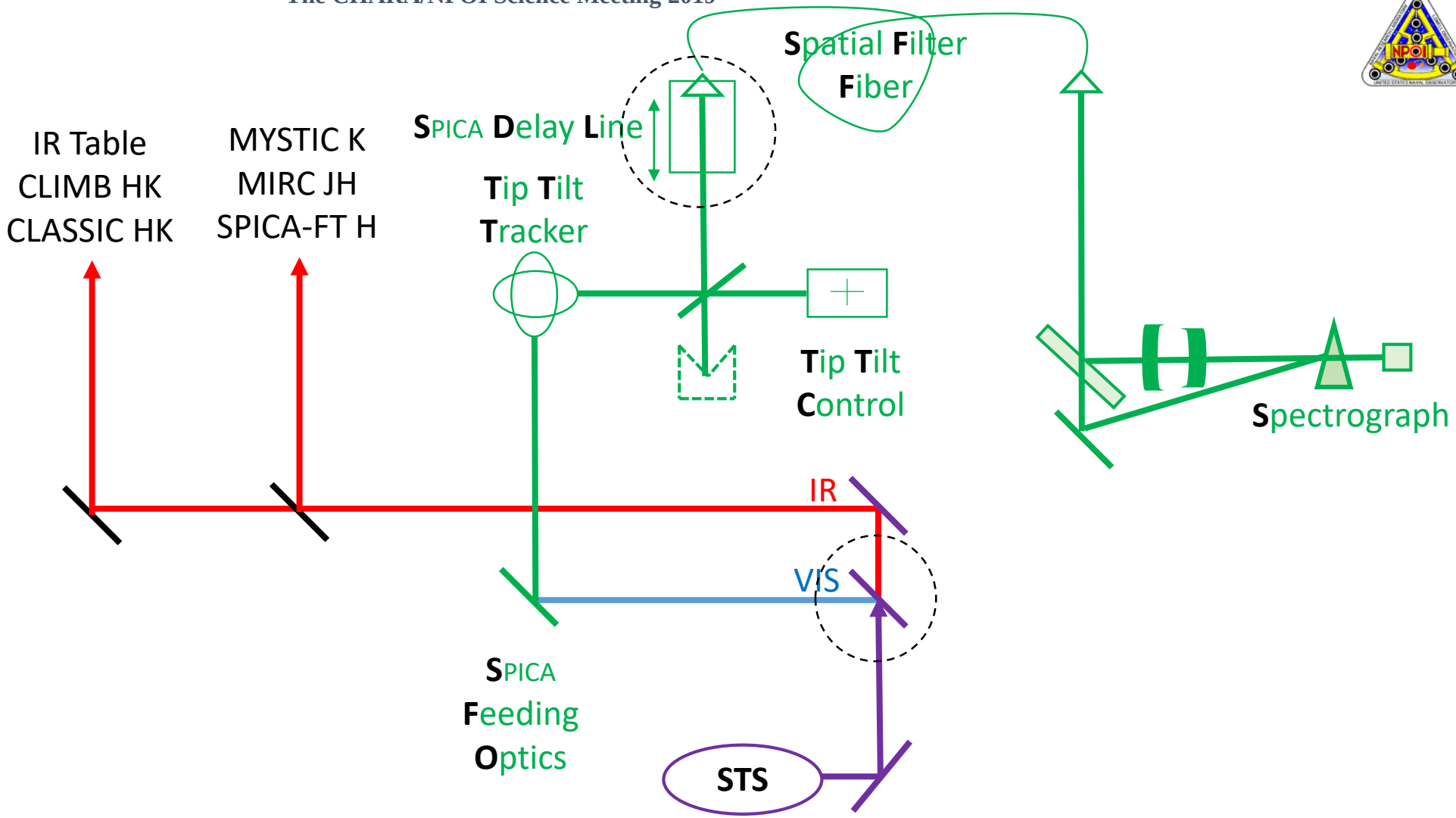
2: Co-Alignment/Cophasing CHARA Reference Source – IR instruments



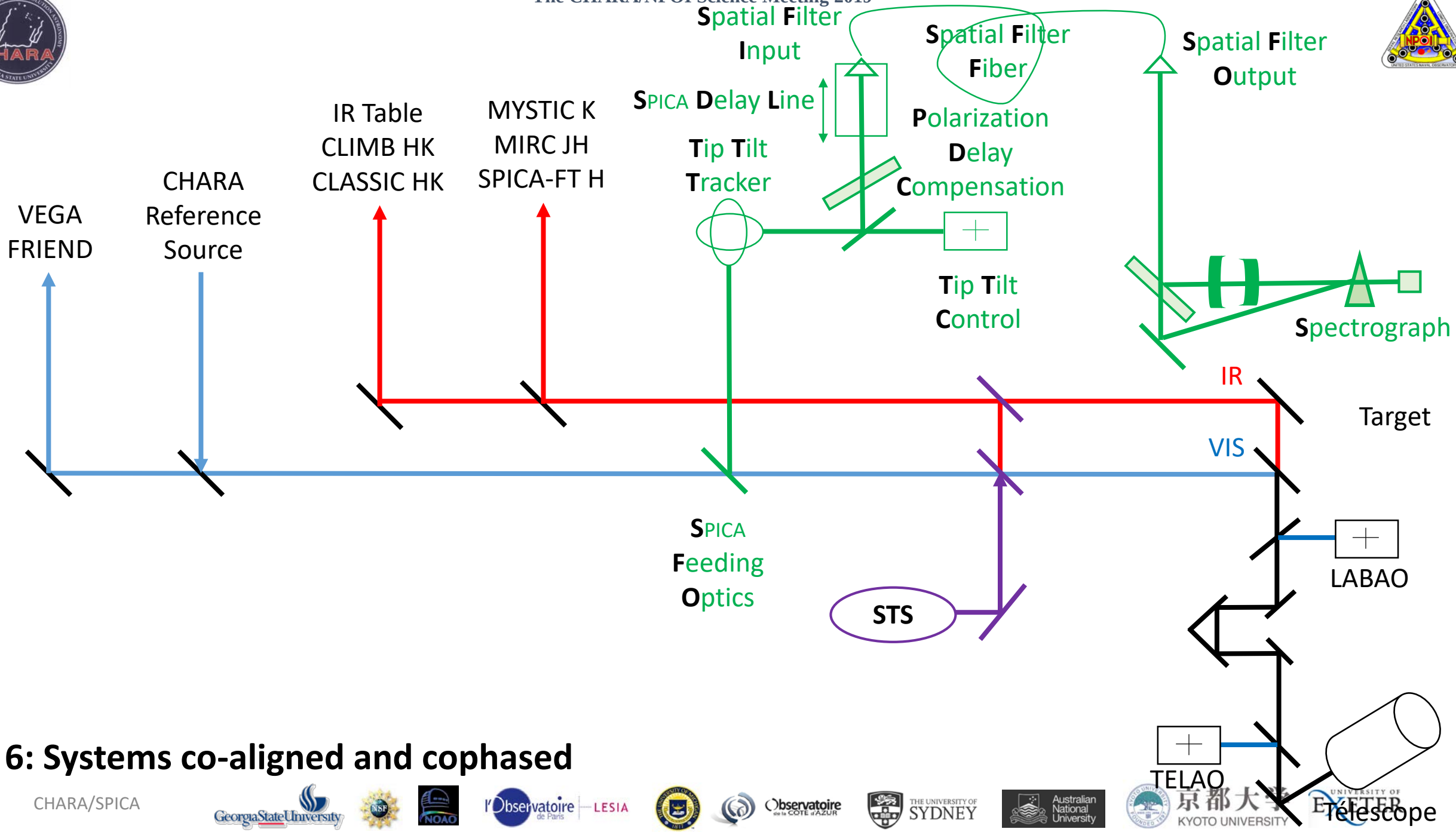
3: Co-Alignment/Cophasing STS– IR instruments



4: Co-Alignment: SPICA (Visible Instrument) – CHARA Reference Source



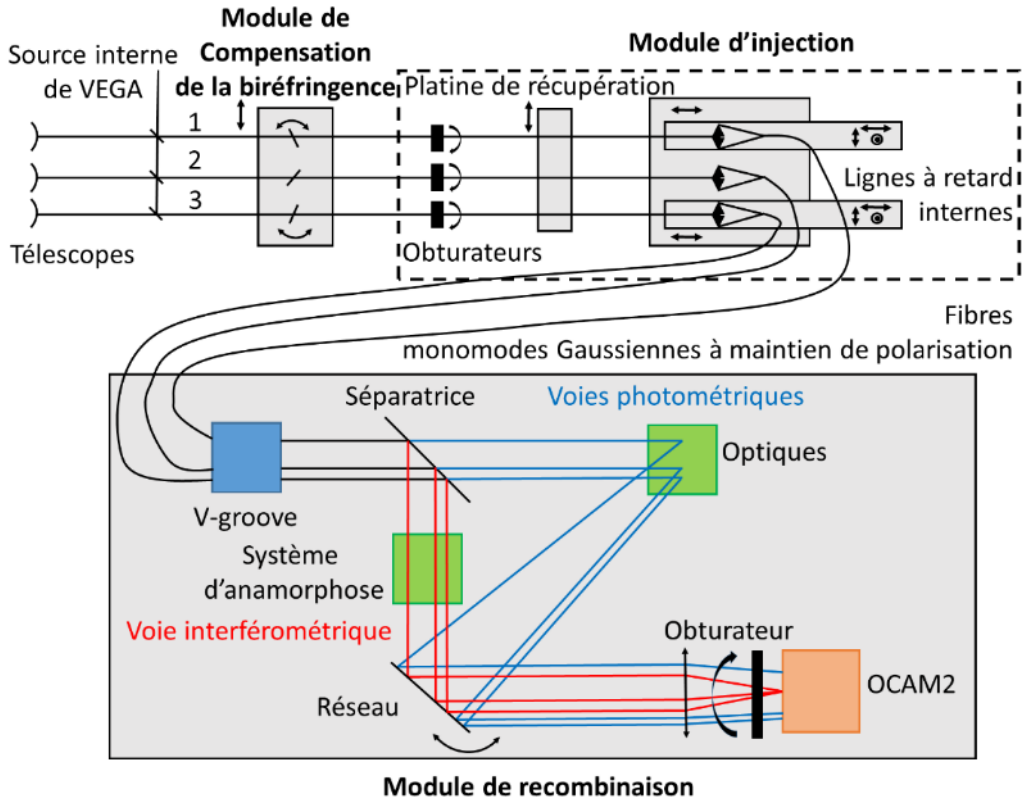
5: Co-Alignment/Cophasing: SPICA – IR Instruments



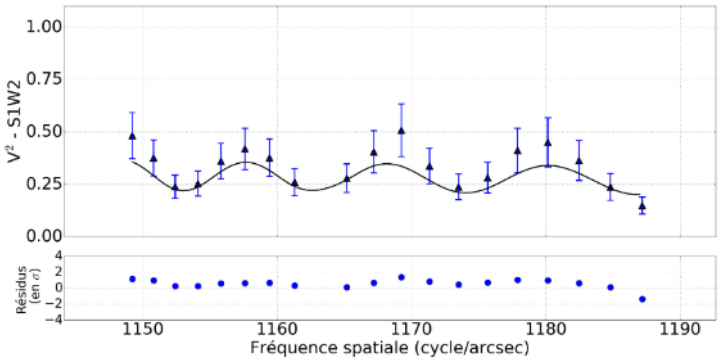
6: Systems co-aligned and cophased

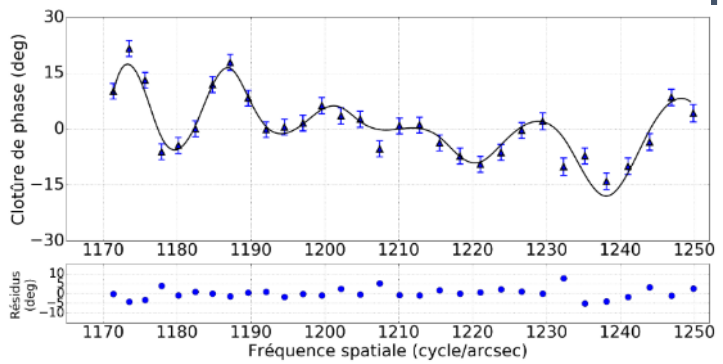
SPICA-VIS: The FRIEND prototype

Limitations of VEGA + AO on CHARA
➔ opportunity for fibered interferometry in the visible
➔ Prototype for know-how and expertise in Nice



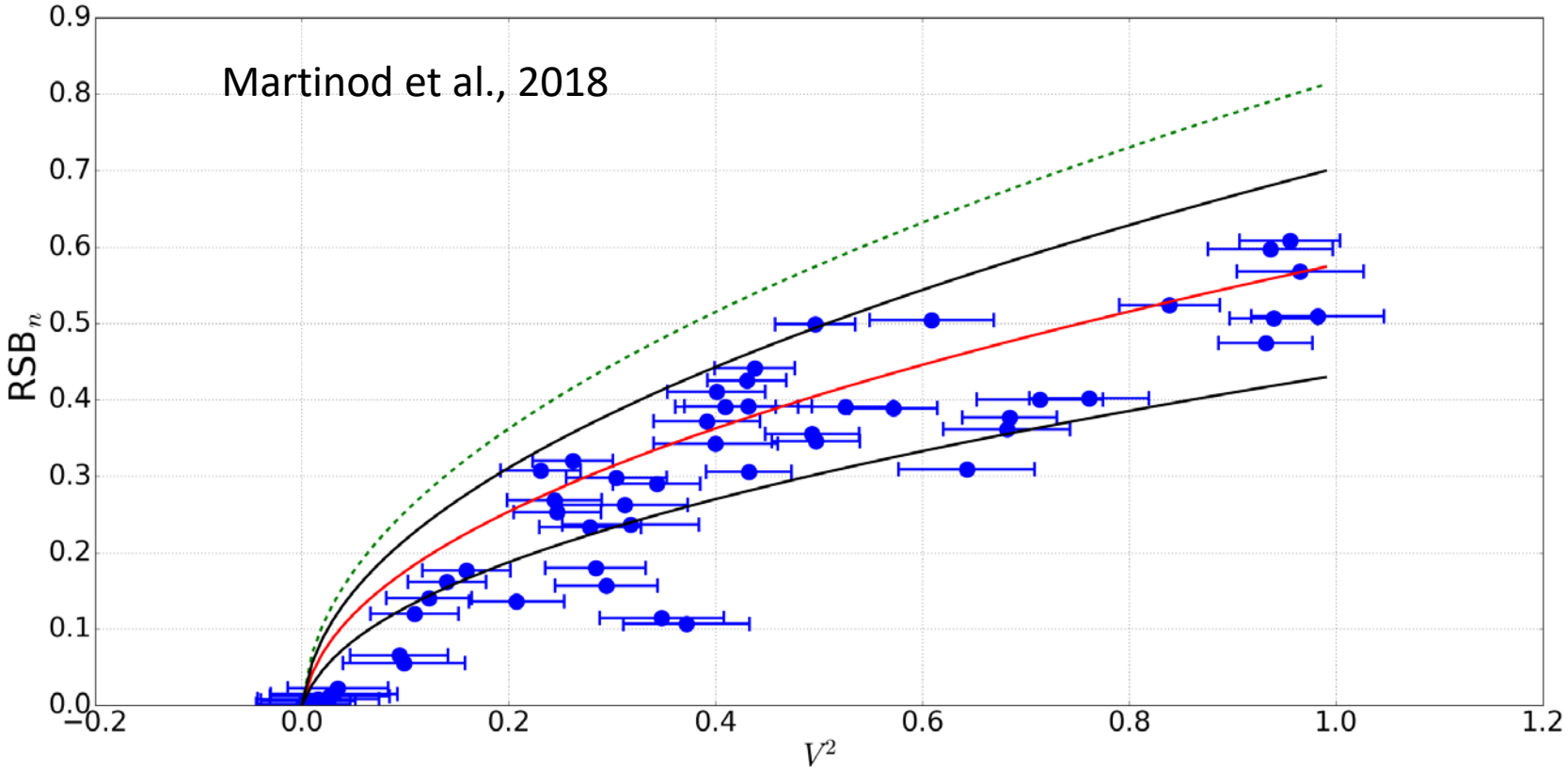
Lessons learned on:
- Visible fibres and injection with partial AO
- Birefringence correction
- EMCCD detector
- Data processing with fibered combiner: V^2 and $C\phi$



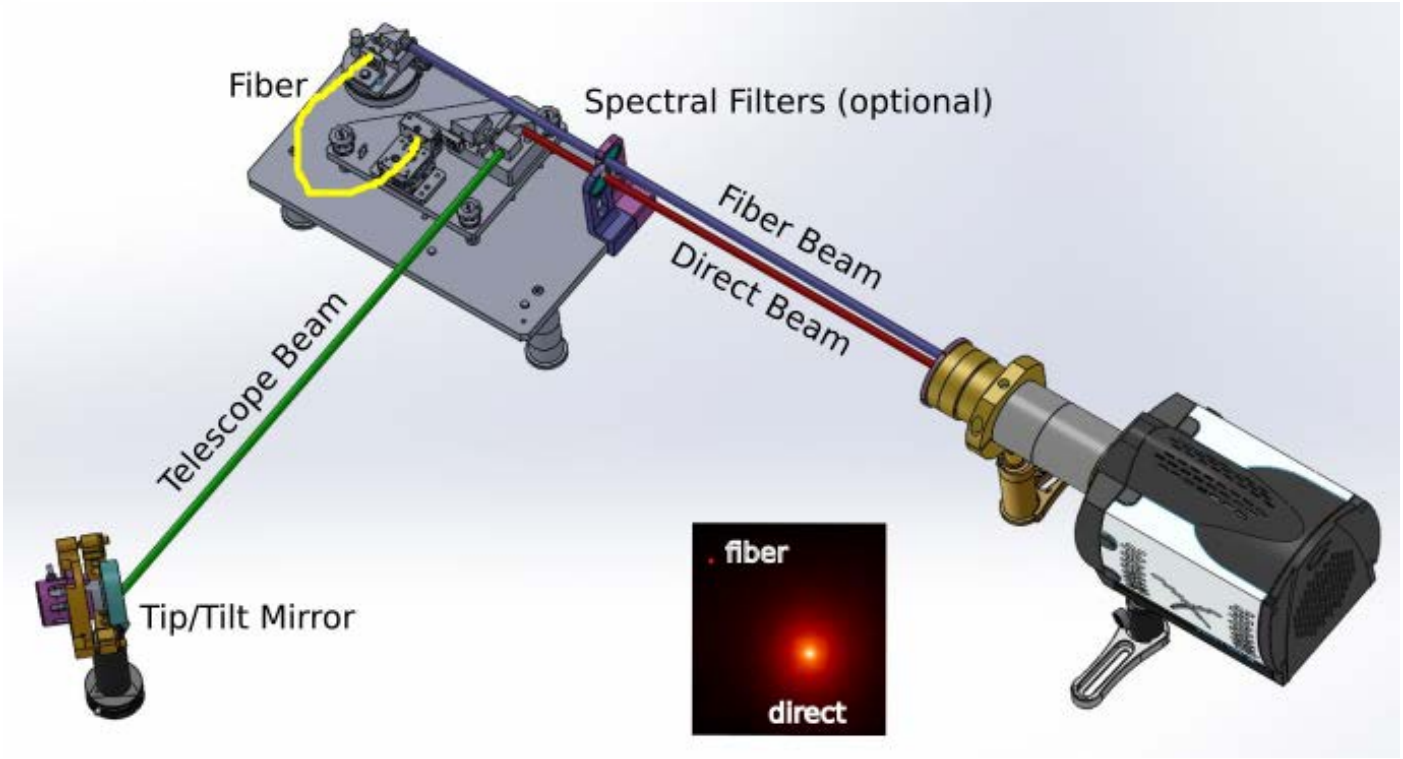


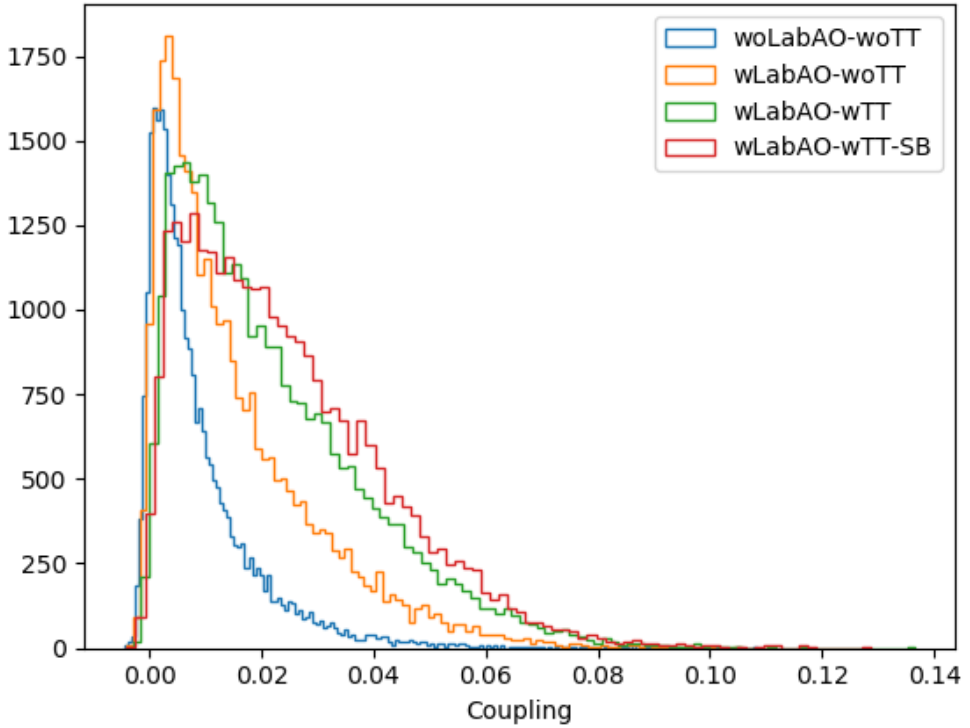
SNR model and sky calibration: Excess Noise Factor

$$RSB_{E_{HF},FRIEND} = \frac{\left(\frac{N_{ph}\, V_{instr}\, V_{obj}{}^2}{N_{tel}}\right)^2 \widetilde{Gab_{ij}}\, \sqrt{N_{img}}}{\sqrt{\text{PhotonNoise} + \text{ReadNoise} + \text{CoupledTerms}}\, \sqrt{N_{\text{pic-frange}}}}$$



CESAR : Coupling Efficiency Statistical Analysis and Recording





Test of injection stability (% of images with CE>1%)	
Without LABAO, without TT	30
With LABAO, without TT	54
With LABAO , with TT (V1)	71
With LABAO, with TT (V2)	76

Coupling x3
Stability x2.4

LR Mode and H-band fringe tracking

Longitudinal dispersion or chromatic OPD

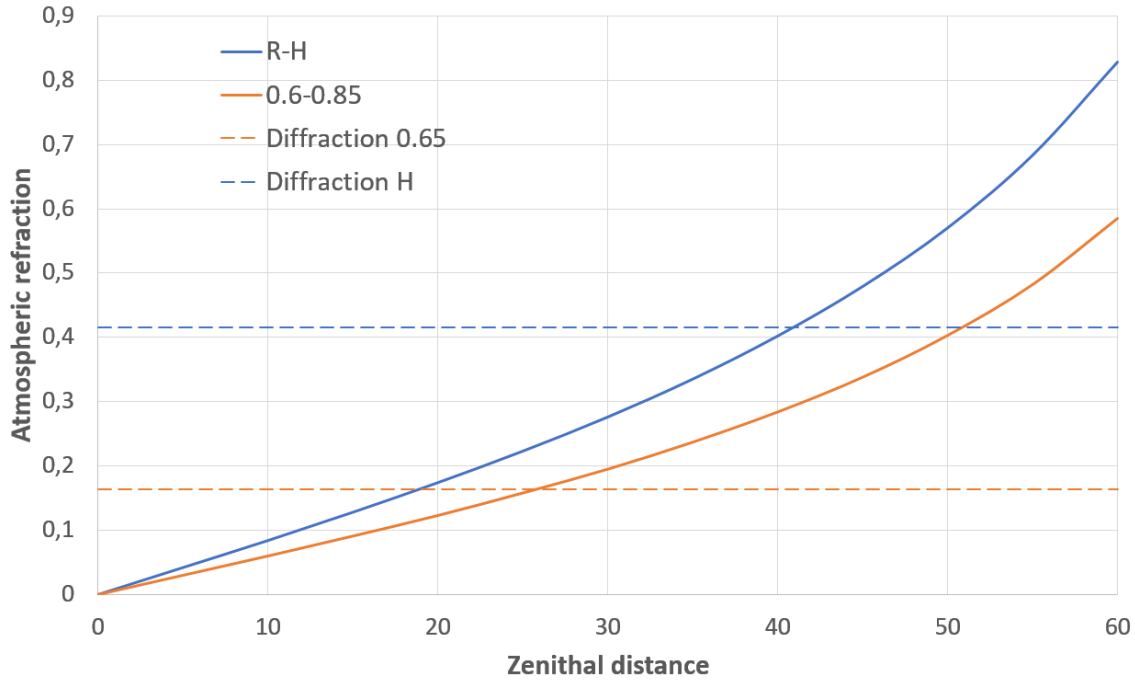
1m of air ⇔ 2.3µm of chromatic OPD between SPICA-VIS and SPICA-FT
⇔ 2λ of chromatic OPD between 0.6 and 0.85µm
⇔ λ/10 inside the H band
⇔ 40nm inside one spectral channel.

Correction is mandatory
Not only in the visible
Choice of a H+R glass?

Atmospheric refraction

R-H: Important to limit the excursion in z during a night

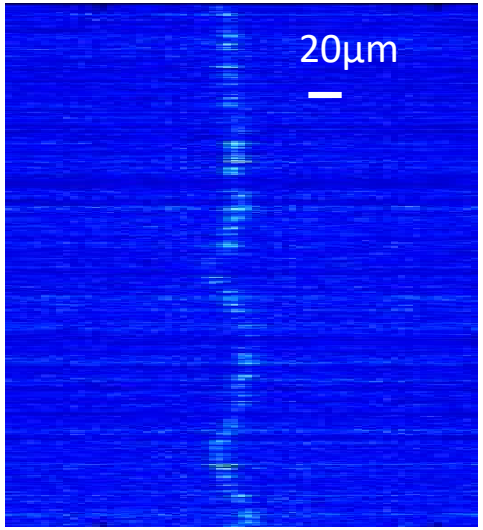
VIS: Probably important to reduce the band.
2 bands of 150nm is probably acceptable.
Also better for the SM fibres



SPICA/CHARA FT: guiding principles and baseline solution

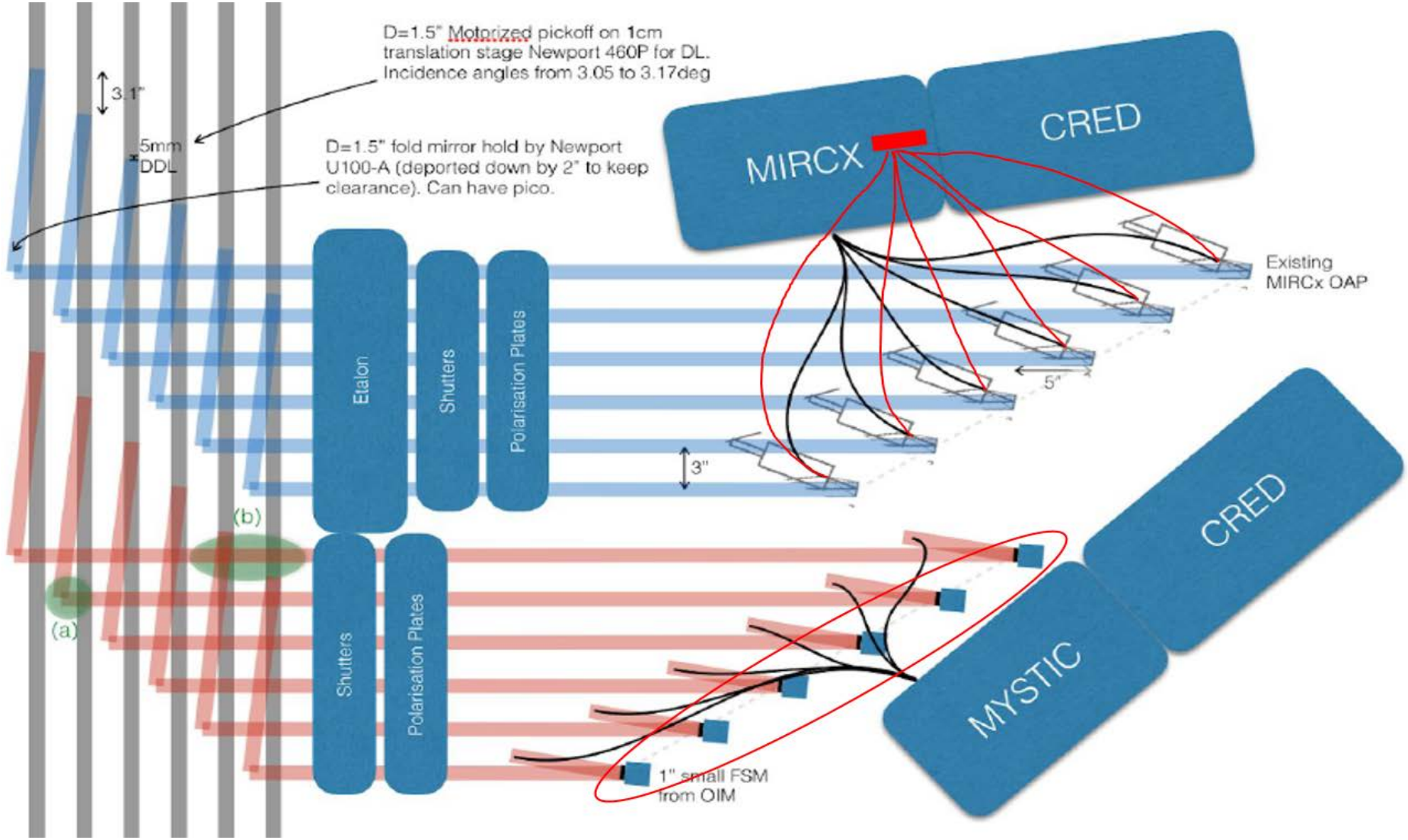
- Do not re-invent the wheel: lessons learned from **CHAMP, GRAVITY-FT**
- Minimization of the development
- Full integration inside the CHARA infrastructure: a general-purpose FT if possible
- Synergy with MIRCx/MYSTIC

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

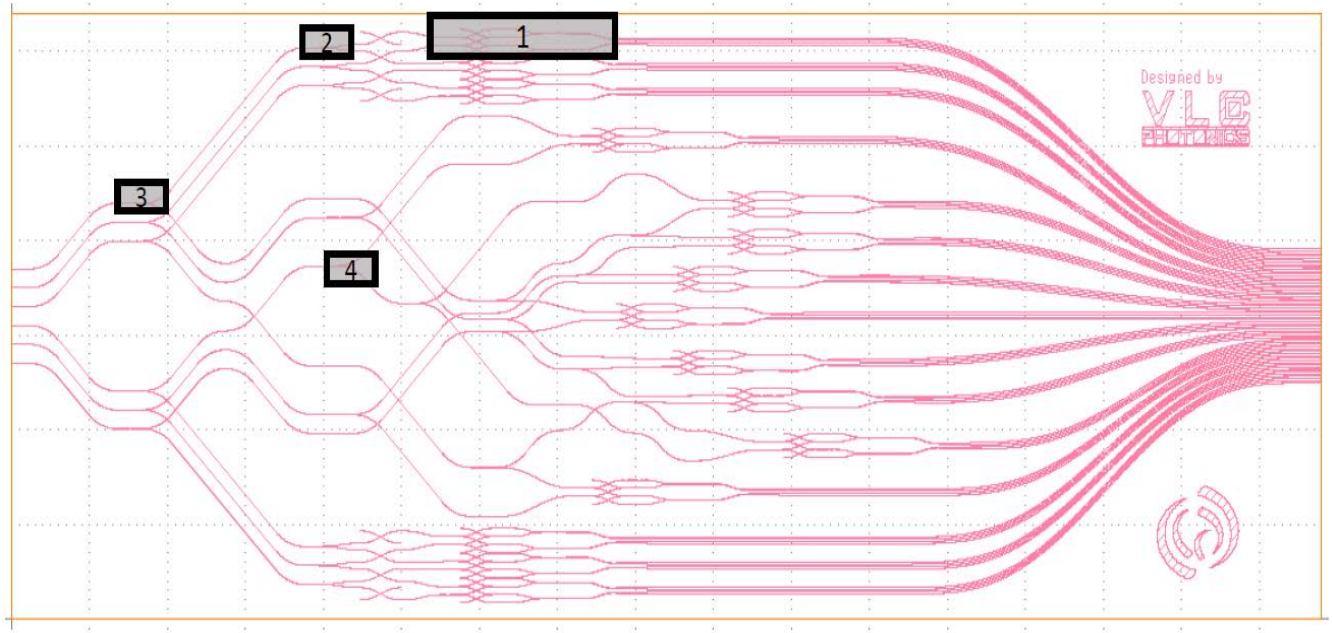


The solution:
- Use the H-band MIRCx fibres to feed a 6T ABCD IO component that will feed the MIRCx Selex detector
- Develop a Phase Sensor + OPD Controller + a State Machine to control the CHARA DL
- Integrate this into the MIRCx software
- OPD Controller should accept Phase Sensor information from SPICA-FT/MIRCx/MYSTIC

SPICA-FT inside MIRCx

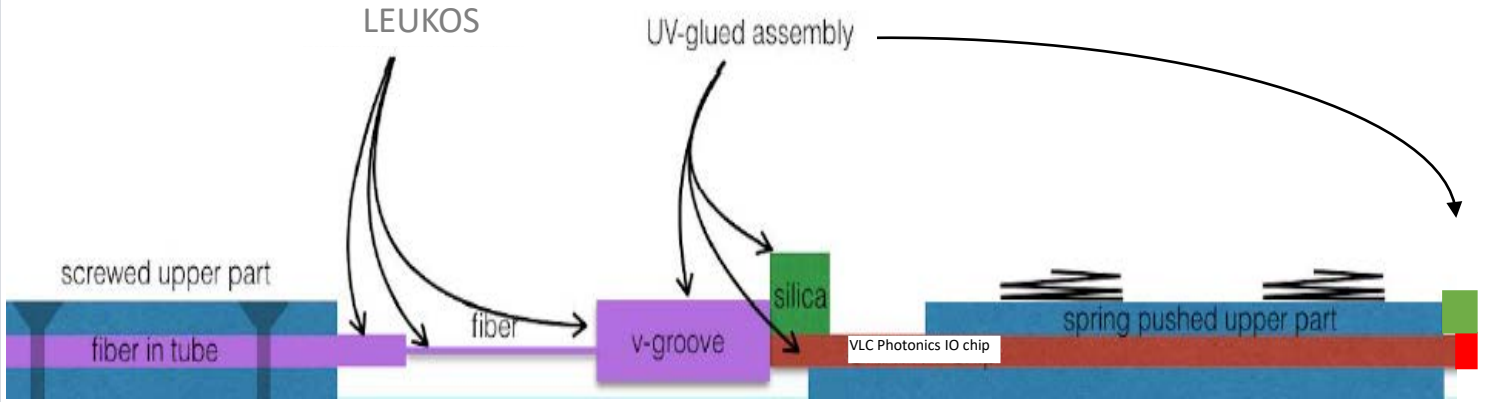


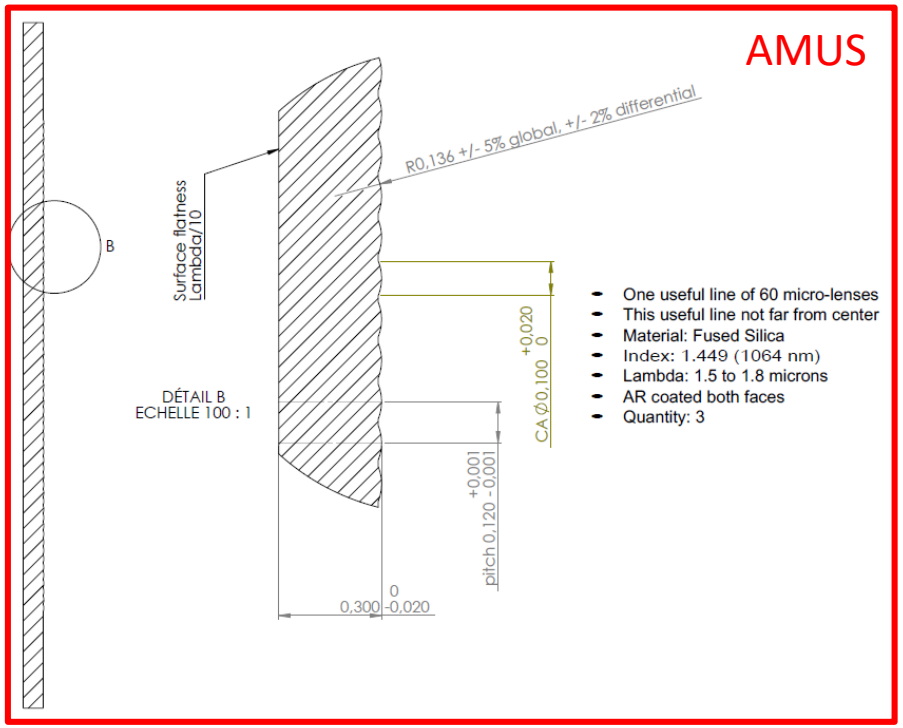
IO component for 6T-ABCD fringe sensor

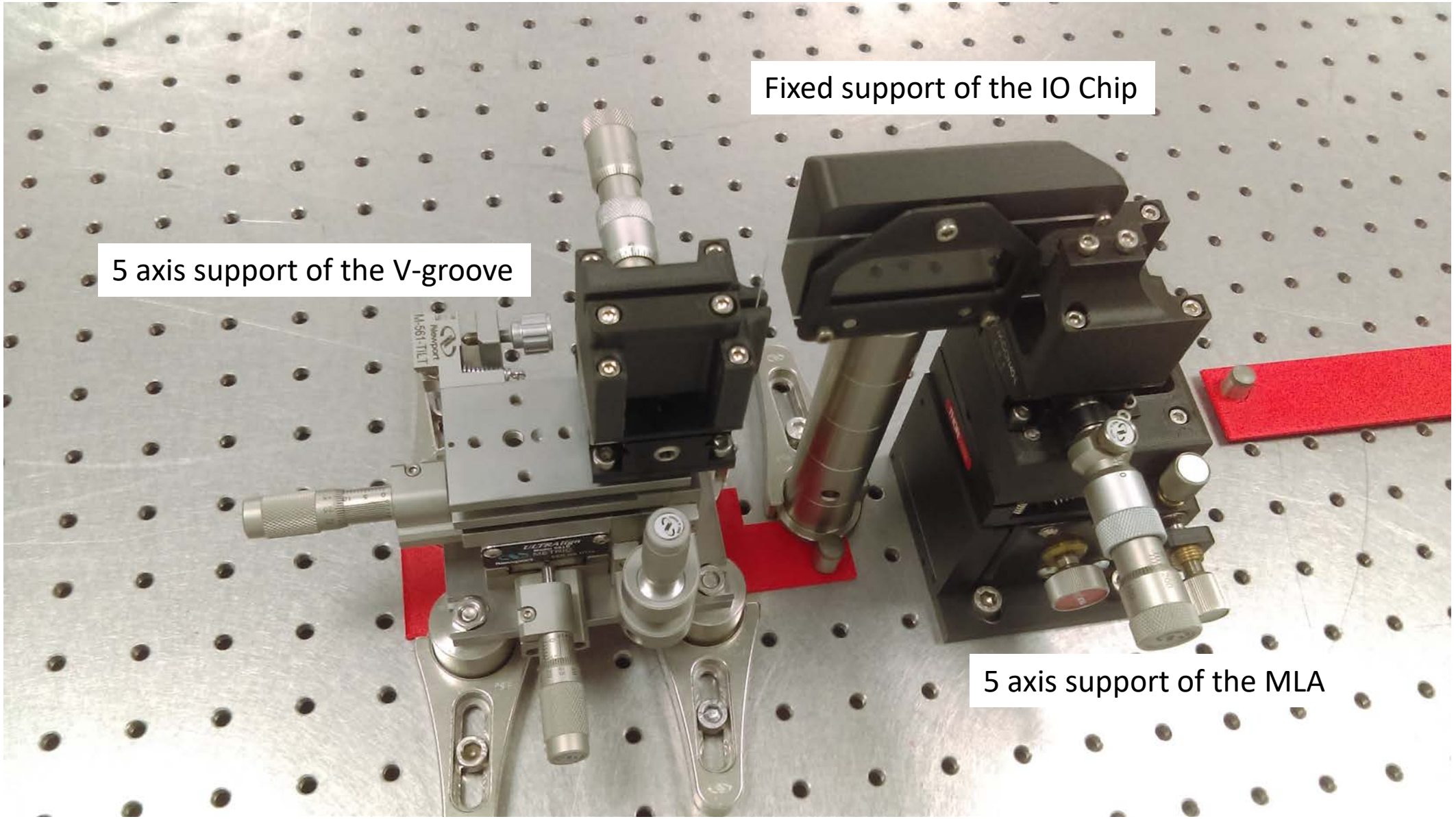


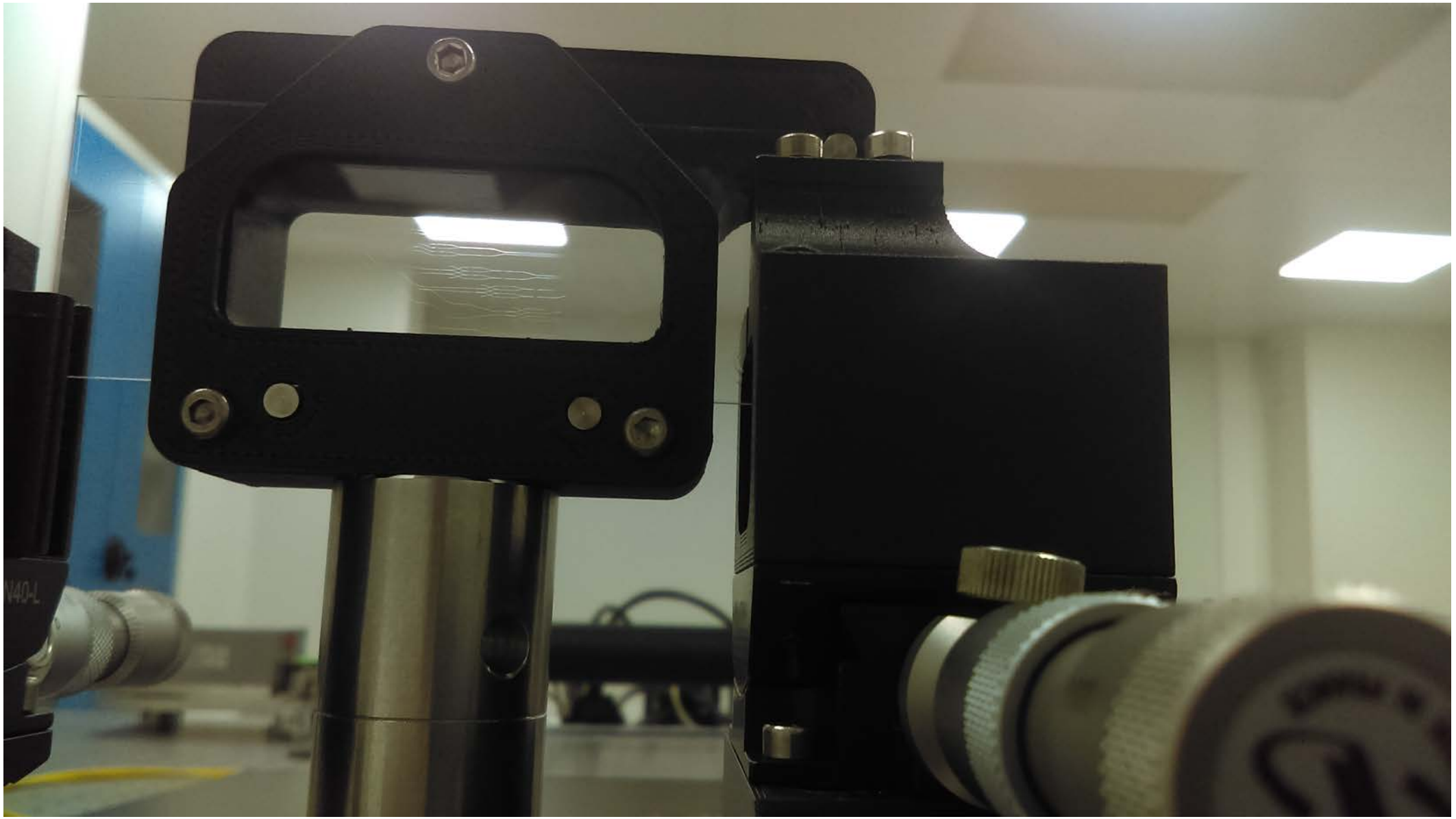
Adapted from a design by Labeye PhD 2008
Similar to GRAVITY (but 6T and H band)

- Single-mode waveguides over the H band
- Number of telescopes to be combined: 6
- Number of baselines to be coded: 15
- Type of fringe coding: ABCD coding

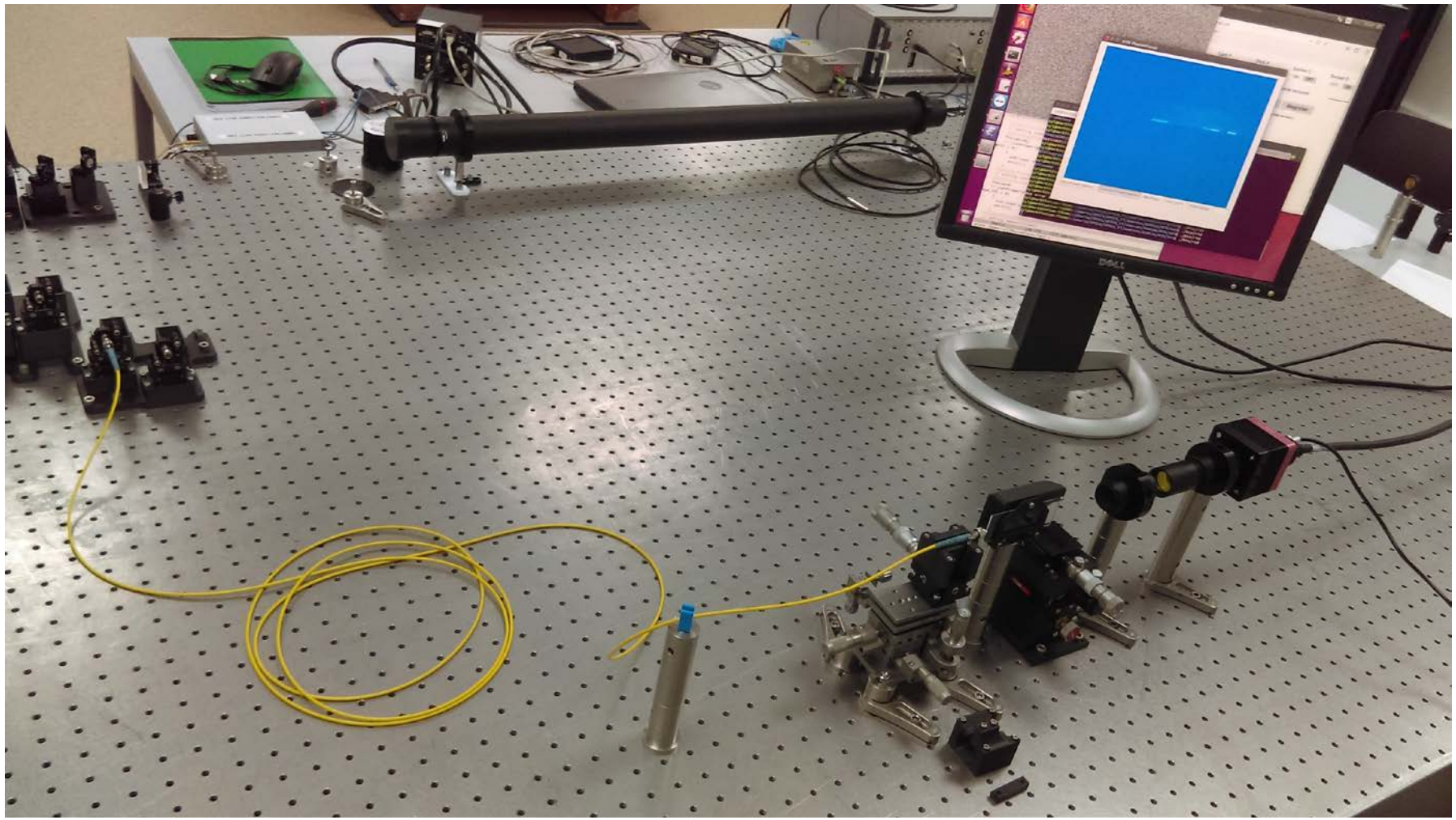





Fixed support of the IO Chip
5 axis support of the V-groove
5 axis support of the MLA



First light of the IO chip (18 Mar 2019…)



Summary SPICA-VIS & SPICA-FT

- SPICA-VIS
  - With VEGA: test of survey mode, observing strategy…
  - With FRIEND: testbed for fibres, birefringence, EMCCD (OCAM² ➔ ANDOR Ixon), pipeline. Sky demonstration, precision of measurements.
  - With CESAR: study and optimisation of the injection into the SM fibres
  - Preliminary design ok, some high level choices to be done
  - Funding for FRIEND, CESAR, ANDOR. No funding for SPICA-VIS for the moment
  - SPICA-VIS: hardware ~200k€ + SG activities + operation cost
  - Schedule not guaranteed but end of 2021 is considered now.

- SPICA-FT
  - Funding CNRS/INSU and UCA (~200 k€). H2020 Opticon 2yr postdoc (Vis. Interferometry: CHARA/SPICA + iVis/VLTI) + Lagrange & OCA.
  - Integration in progress in Nice, lab and software activities.
  - First light inside CHARA and MIRCx considered for Nov-Dec/2019