SPICA *S*tellar *P*arameters and *I*mages with a *C*ophased *A*rray

A new visible 6T spectro-combiner for CHARA

https://lagrange.oca.eu/fr/spica-project-overview

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& S. Kraus, S. Lacour, J.B. Le Bouquin, J. Monnier, & S. Albrecht

& the CHARA staff (special thanks to Judit!)

Origins of the project

- **Main scientific idea**
  - Growing interest for fundamental parameters of star: Radius (θ+π), Effective temperature (θ+Fbol) for exoplanet host stars, distance scale (with SBCR), asteroseismology. Analysis of the stellar noise due to “activity”
  - Importance to develop an homogeneous and large survey to cover a wide region of the HR diagram.

- **Opportunity**
  - Development of the AO program on CHARA
  - Identification of the main limitations of VEGA (detector, multimode regime) and solutions (FRIEND)
  - Huge progress on EMCCD, single mode fibres, integrated optics device (Gravity Fringe Tracker)

- **Top level requirements**
  - Quality of measurements: Spatial filtering, 6T operation
  - Sensitivity up to mag 8 (10 ideally): low spectral resolution, fringe tracking, optimised injection
  - Survey mode with optimised night strategies
  - Combination of R, (J) H K data

SPICA in a nutshell

- *A H-band 6T-ABCD fringe sensor aiming at performing a group delay and phase delay tracking of the fringes.*
- A All-In-One 6T combiner (600-900nm) with three dispersion

MODES	Nb of SpCh	SpCh	Spectral Band	MagLim V^2=0.6	MagLim V^2=0.6 + FT	MagLim Vdiff	MagLim Vdiff+FT
LR: R=140	60	~5nm	300nm	6.5	11.5		
MR: R=4400	500	0.17nm	85nm			5.5	9.5
HR: R=13000	500	0.06nm	29nm			4.5	8.5

MagLim: V^2: SNR=10, 10mn of integration, for one spectral channel
Vdiff: [SNR=10, $\sigma\phi$<5°], V^2=0.6 in the reference channel, 30mn of integration, for one spectral channel

SNR calculator based on FRIEND calibration (Martinod+2018), CHARA-AO hypothesis **SR=5%** *, SPICA estimations*
Validation to be done on sky beginning of 2022

Scientific Requirements: θ_{LD} and (θ_{LD} +LD) measurements

θ_{LD} only with hypothesis on the LD law

$\sigma\theta/\theta$=1%

θ_{LD} and LD from SPICA

Dwarfs	Challouf			Salsi-1			Salsi-2		
SpTy	O	B0	A0	F5	G7	K4	M0	M3	M4
V // V-K	-2	-1	0	1	2	3	4	5	6
0	0,10	1,00	3,35	6,28	11,82	22,25	39,94	70,70	125,14
1	0,06	0,63	2,11	3,96	7,46	14,04	25,20	44,61	78,96
2	0,04	0,40	1,33	2,50	4,71	8,86	15,90	28,14	49,82
3	0,02	0,25	0,84	1,58	2,97	5,59	10,03	17,76	31,43
4	0,02	0,16	0,53	0,99	1,87	3,53	6,33	11,20	19,83
5	0,01	0,10	0,33	0,63	1,18	2,23	3,99	7,07	12,51
6	0,01	0,06	0,21	0,40	0,75	1,40	2,52	4,46	7,90
7	0,00	0,04	0,13	0,25	0,47	0,89	1,59	2,81	4,98
8	0,00	0,03	0,08	0,16	0,30	0,56	1,00	1,78	3,14
9	0,00	0,02	0,05	0,10	0,19	0,35	0,63	1,12	1,98
10	0,00	0,01	0,03	0,06	0,12	0,22	0,40	0,71	1,25

Giants	Challouf			Salsi-1			Salsi-2		
SpTy	O	B0	A0	F5	G7	K4	M0	M3	M4
V // V-K	-2	-1	0	1	2	3	4	5	6
0	0,24	1,09	3,16	6,72	11,79	20,68	36,41	62,26	106,46
1	0,15	0,69	1,99	4,24	7,44	13,05	22,97	39,28	67,17
2	0,10	0,44	1,26	2,68	4,69	8,23	14,49	24,79	42,38
3	0,06	0,27	0,79	1,69	2,96	5,20	9,15	15,64	26,74
4	0,04	0,17	0,50	1,07	1,87	3,28	5,77	9,87	16,87
5	0,02	0,11	0,32	0,67	1,18	2,07	3,64	6,23	10,65
6	0,02	0,07	0,20	0,42	0,74	1,30	2,30	3,93	6,72
7	0,01	0,04	0,13	0,27	0,47	0,82	1,45	2,48	4,24
8	0,01	0,03	0,08	0,17	0,30	0,52	0,91	1,56	2,67
9	0,00	0,02	0,05	0,11	0,19	0,33	0,58	0,99	1,69
10	0,00	0,01	0,03	0,07	0,12	0,21	0,36	0,62	1,06

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2	0,04	0,40	1,33	2,50	4,71	8,86	15,90	28,14	49,82
3	0,02	0,25	0,84	1,58	2,97	5,59	10,03	17,76	31,43
4	0,02	0,16	0,53	0,99	1,87	3,53	6,33	11,20	19,83
5	0,01	0,10	0,33	0,63	1,18	2,23	3,99	7,07	12,51
6	0,01	0,06	0,21	0,40	0,75	1,40	2,52	4,46	7,90
7	0,00	0,04	0,13	0,25	0,47	0,89	1,59	2,81	4,98
8	0,00	0,03	0,08	0,16	0,30	0,56	1,00	1,78	3,14
9	0,00	0,02	0,05	0,10	0,19	0,35	0,63	1,12	1,98
10	0,00	0,01	0,03	0,06	0,12	0,22	0,40	0,71	1,25

DWARFS

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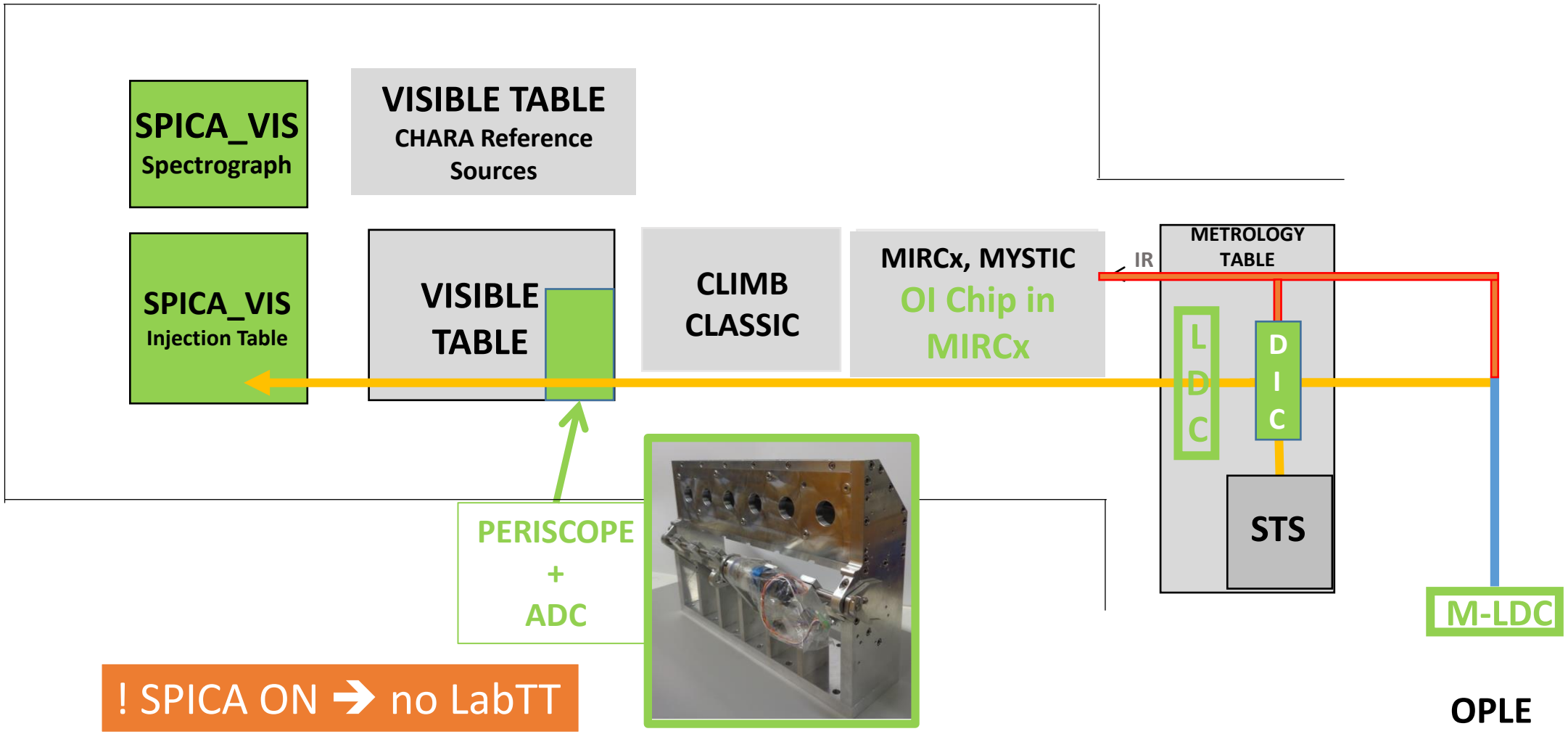
3	0,06	0,27	0,79	1,69	2,96	5,20	9,15	15,64	26,74
4	0,04	0,17	0,50	1,07	1,87	3,28	5,77	9,87	16,87
5	0,02	0,11	0,32	0,67	1,18	2,07	3,64	6,23	10,65
6	0,02	0,07	0,20	0,42	0,74	1,30	2,30	3,93	6,72
7	0,01	0,04	0,13	0,27	0,47	0,82	1,45	2,48	4,24
8	0,01	0,03	0,08	0,17	0,30	0,52	0,91	1,56	2,67
9	0,00	0,02	0,05	0,11	0,19	0,33	0,58	0,99	1,69
10	0,002	0,011	0,032	0,067	0,118	0,207	0,364	0,623	1,065

GIANTS

SPICA in the lab



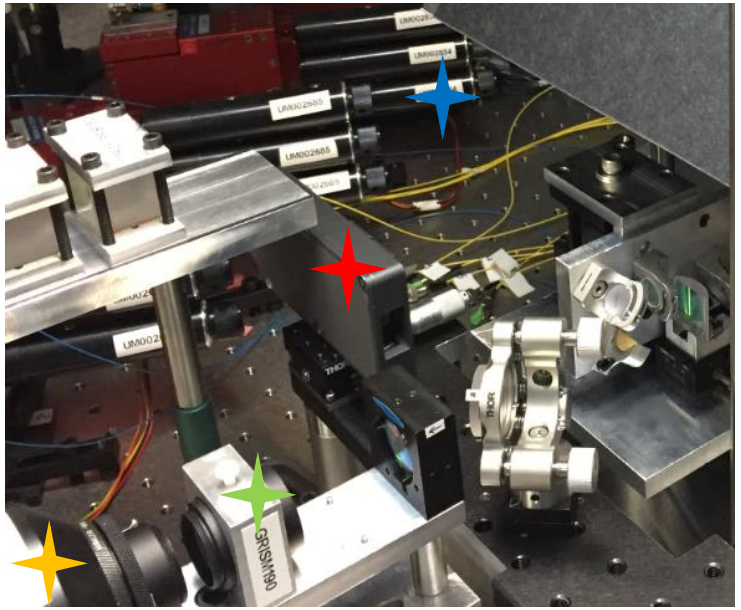
SPICA-FT

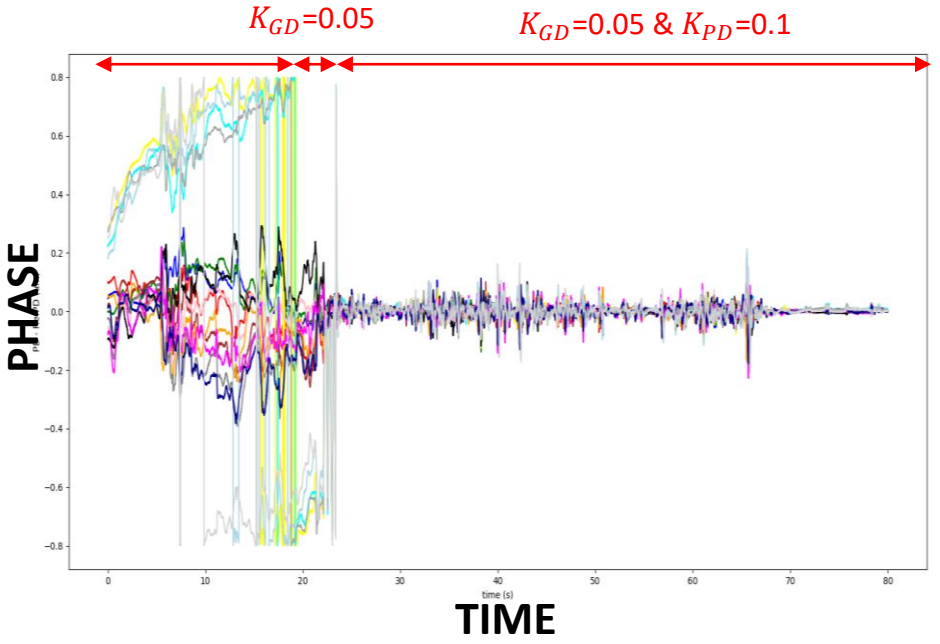
- Fibered IO device performing a **6T ABCD H band combiner**, using the **MIRCx fiber injection systems**, **the MIRCx spectrograph**, and the **CRedOne detector**.

- Specifications:
  - Exposures from 20ms (GD) to 200ms (GD+PD) in the visible, λ/8 rms
  - Goal: reaching a few seconds of integration time

- First light in January 2020 (5T, GD only)
- Optimisation of the GD+PD loops on the testbed in Nice – State Machine
- 6T fringe search operational

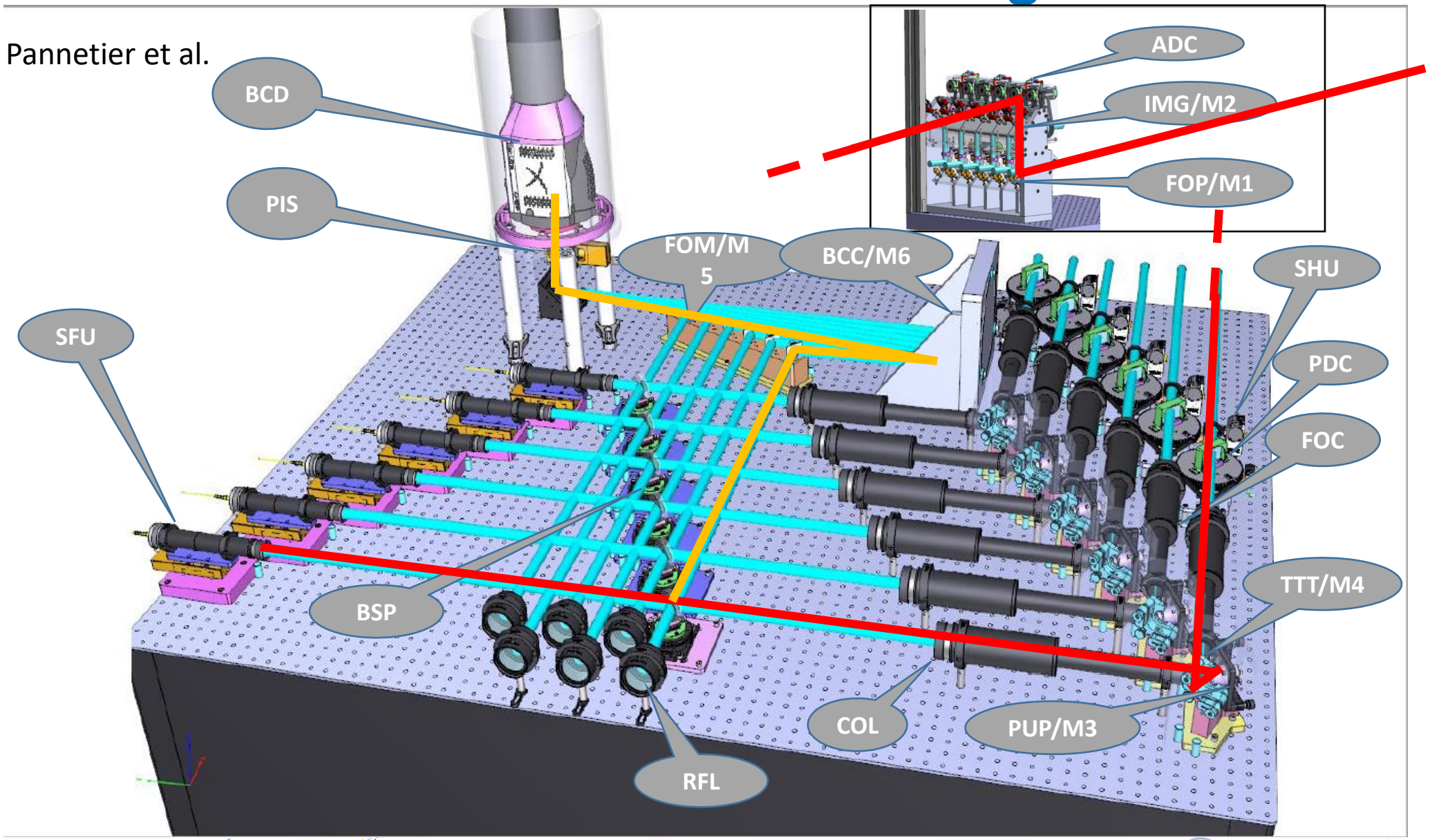
- Ongoing activities
  - On-sky tests, also including the new OPLE control system (remote and May?)
  - 3rd generation of the integrated optics chip: correction of internal instrumental CP, optimisation of the splitter function (summer 2021)
  - Addition of a predictive filtering (End of 2021 ?)



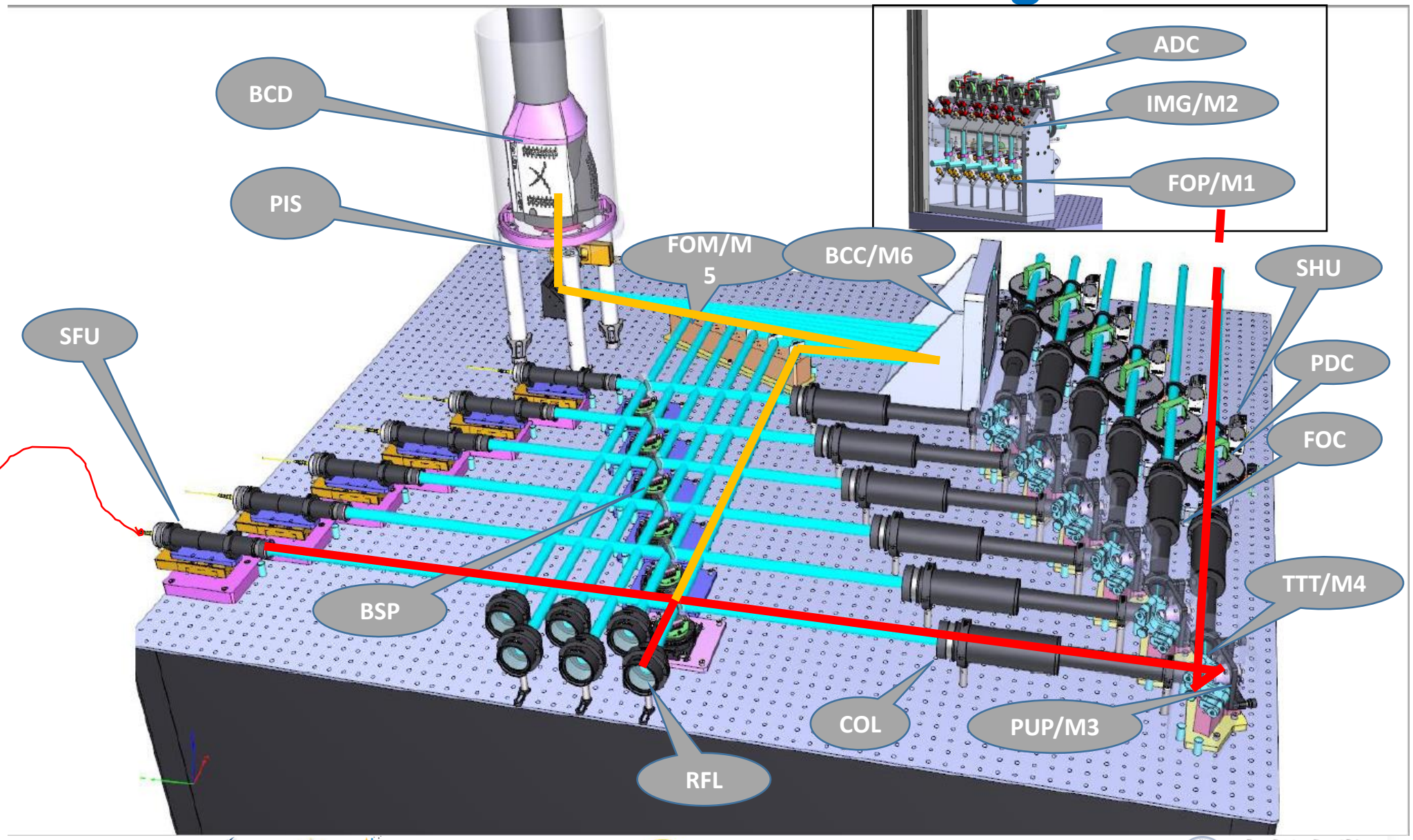


SPICA-VIS General design

SPIE 2020, Pannetier et al.



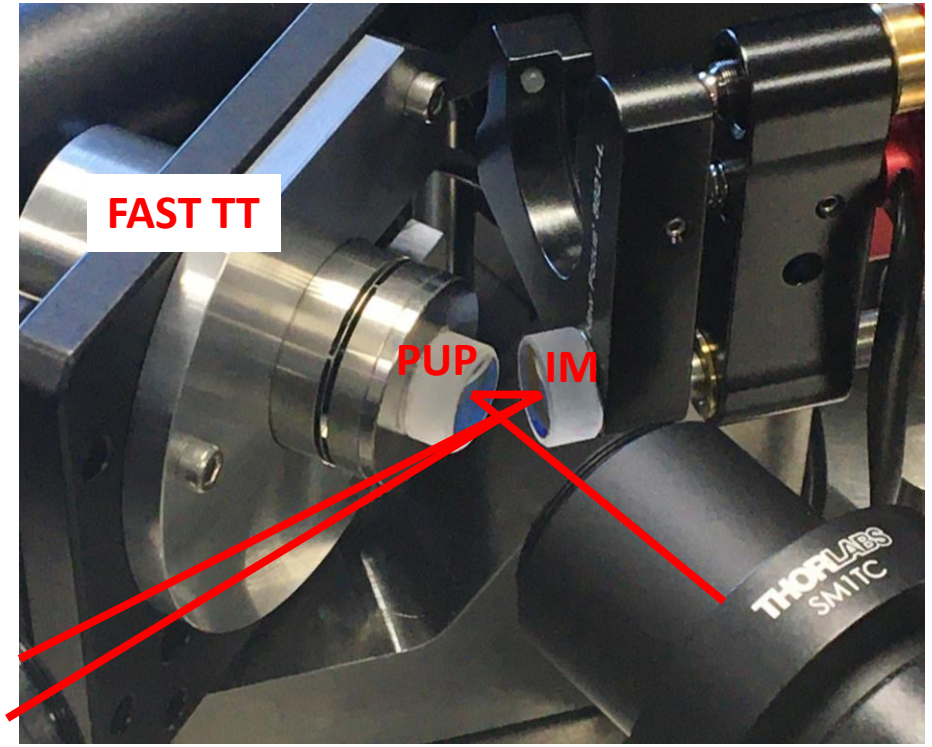
SPICA-VIS General design



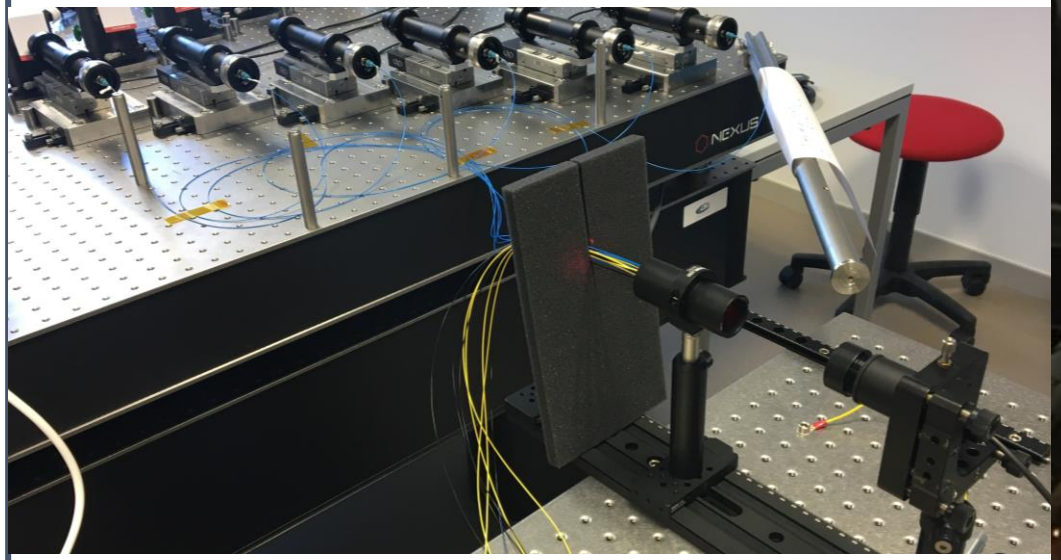
SPICA-VIS injection table

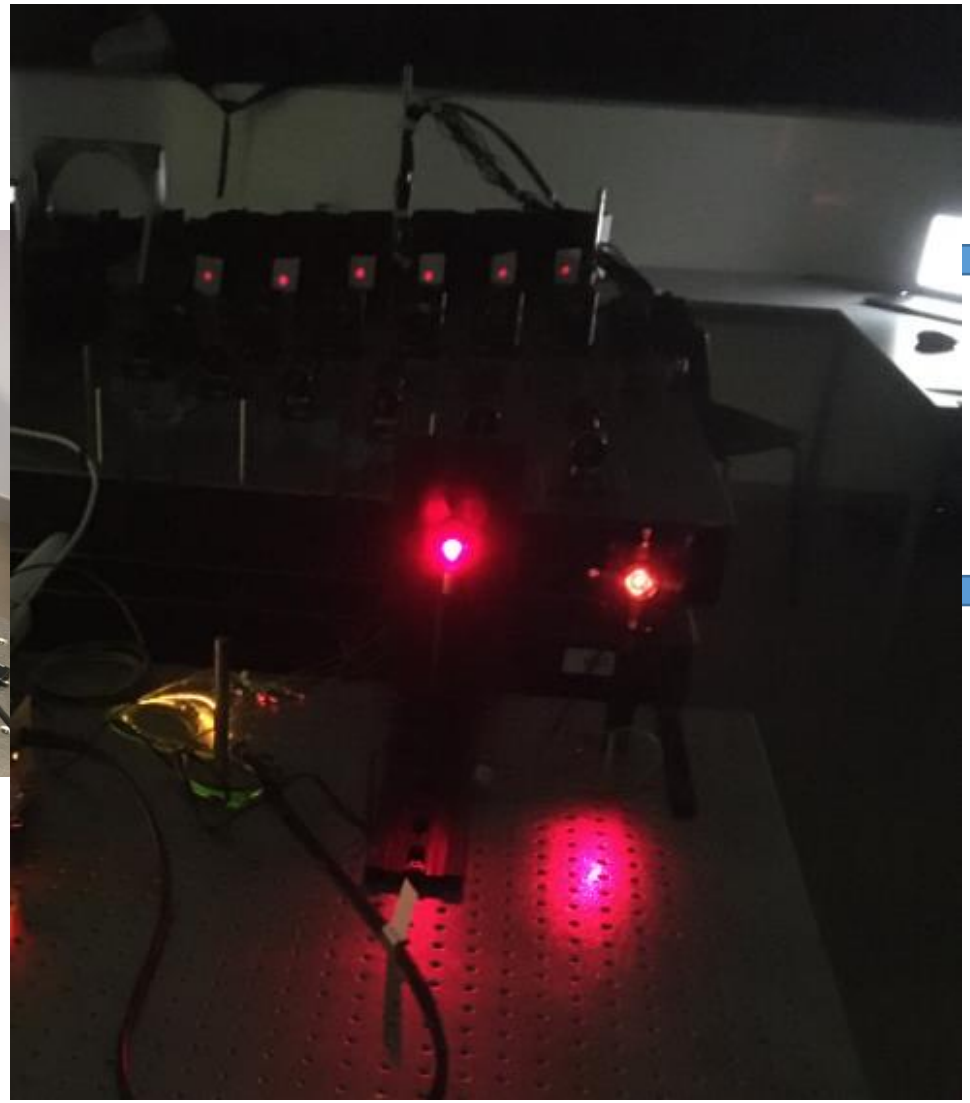
Every thing has been designed to optimize the injection in the fibres:

- Optical quality and high performance coatings
- Alignment in image and pupil plane control
- Fast tip/tilt correction to compensate the partial AO correction
- ADC for a good coupling all over the spectral band
- Fibre Back Illumination to avoid a time-expensive fibre explorer solution



SPICA-VIS injection table "*first light*" 10 Mar 2021





6 spots on the FOC locations

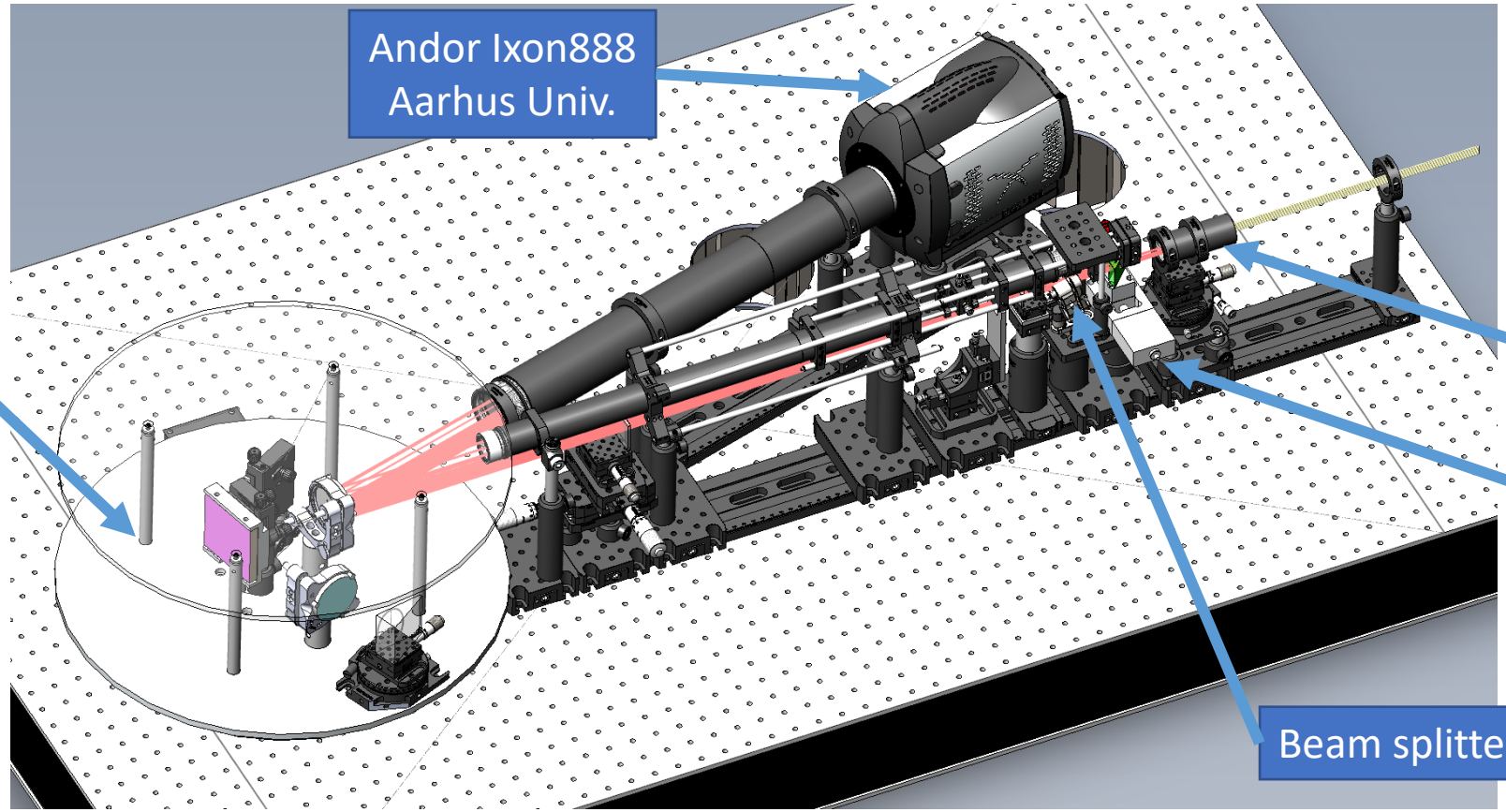
V-groove Fiber Back Illumination

Credit J. Dejonghe

SPICA-VIS spectrograph table

At the output of the V-groove, separation of photometric and interferometric channel
Anamorphosis of the interferometric channel and fringes in the image plane after the dispersion
Dispersion of the photometric channel in the 'pupil' plane
Optical design by CP, mechanical design by JD

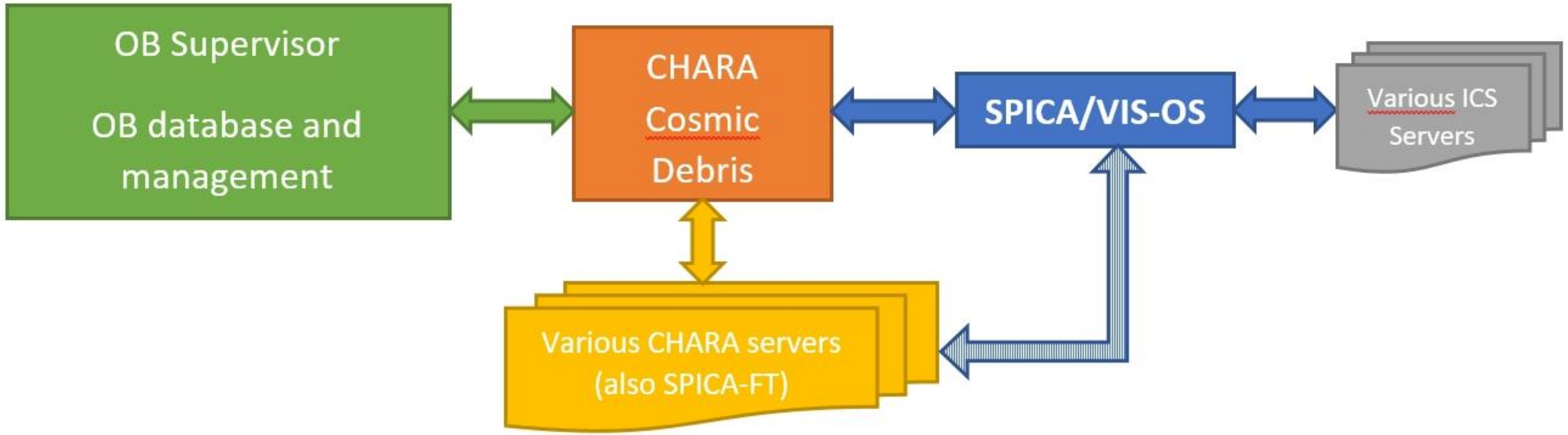
Dispersion
1 double prism
2 gratings
1 mirror (no disp.)
1 single rotating stage



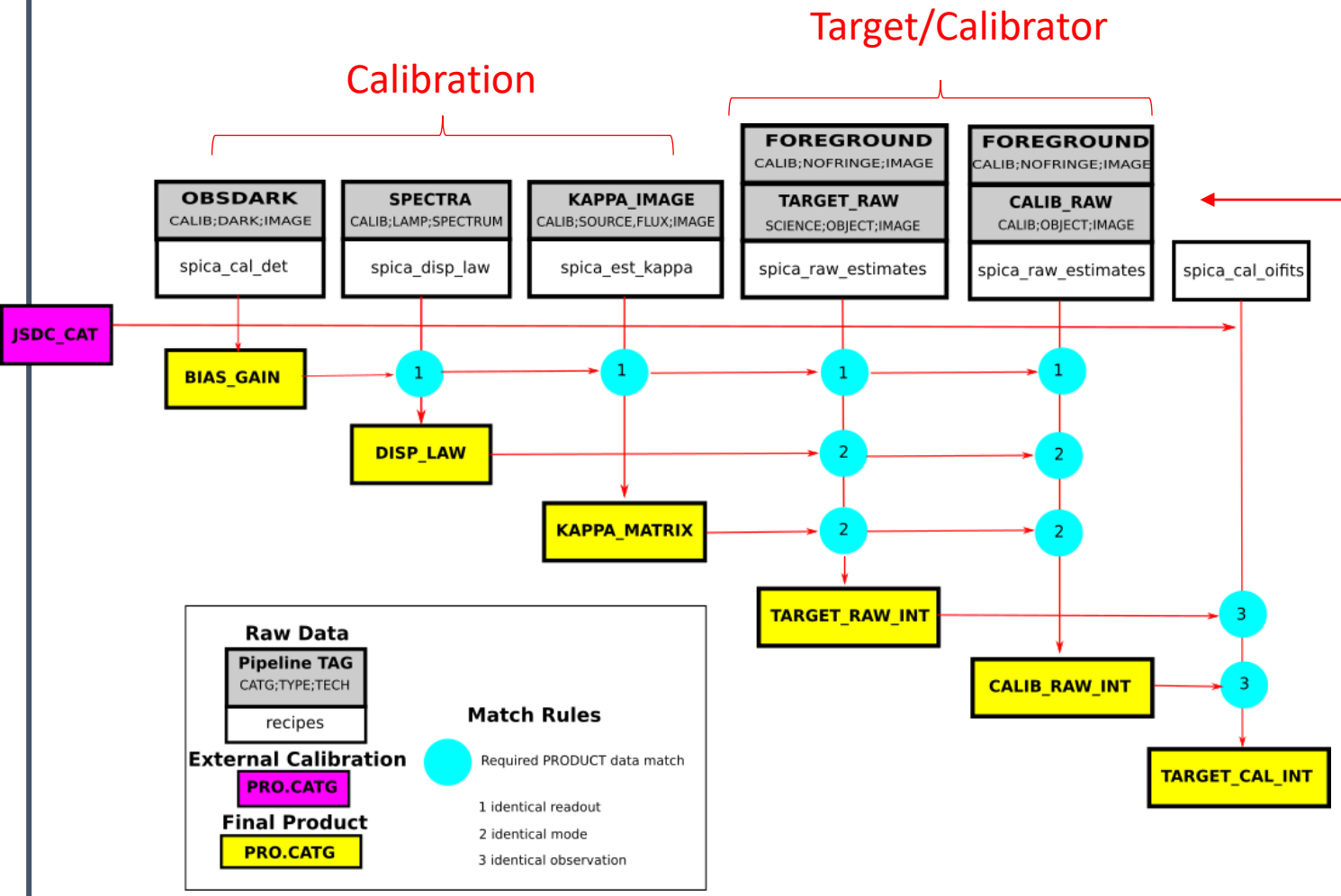
SPICA-VIS Observing Software

Global architecture

- CHARA Cosmic Debris is the highest client (including SPICA-FT server)
- OB supervisor for observation information (JMMC A2P2 principle adapted to CD)
- OS observation information from CD
- OS control of all SPICA-VIS devices thru servers



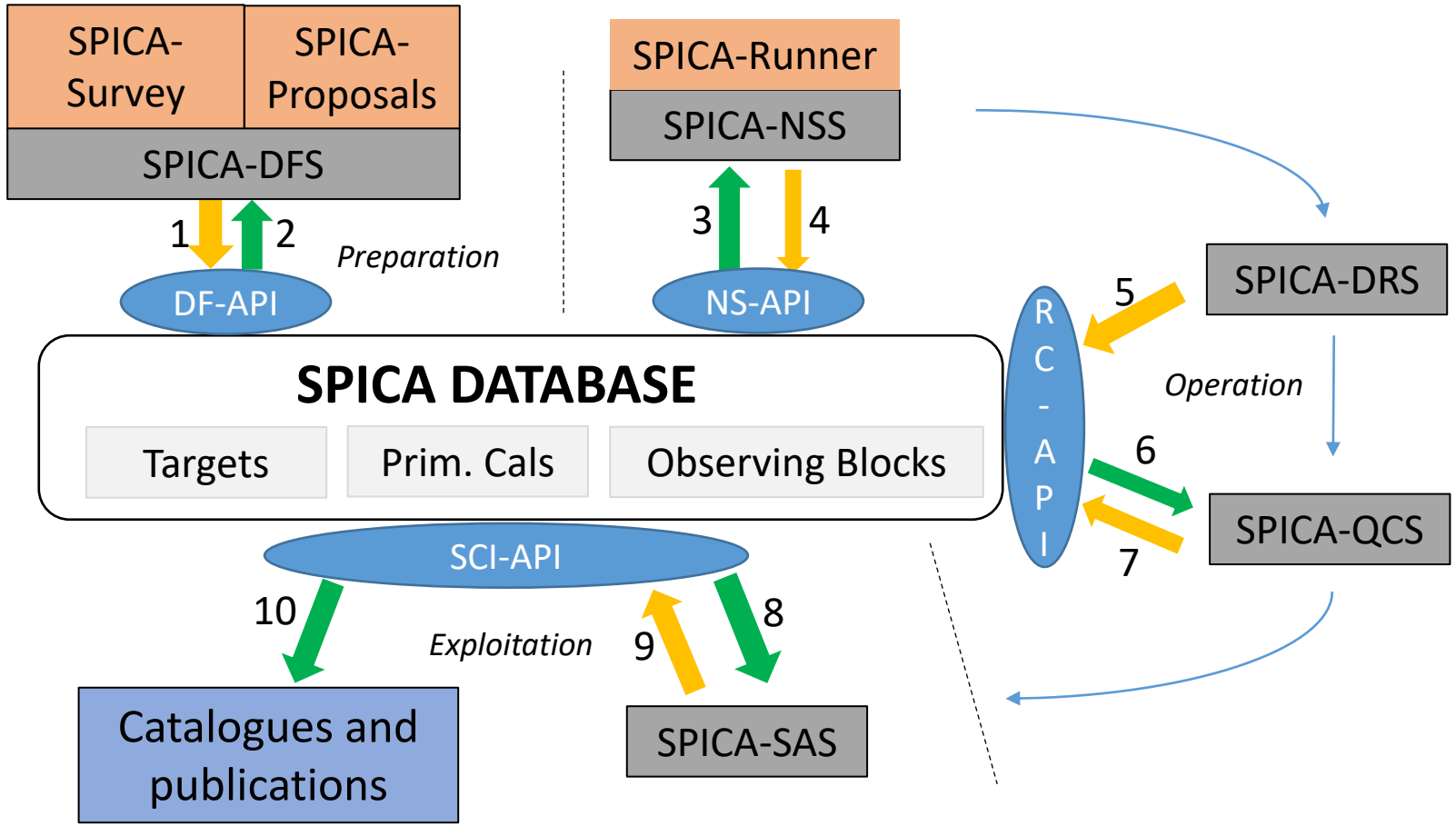
SPICA-VIS DRS (heritage from VLTI/MATISSE & FRIEND)



Match Rule	Keyword Name	Keyword Description
Identical Readout	HIERARCH DET NAME HIERARCH DET DIT HIERARCH DET GAIN	Detector Name Detector Frame Time Detector Gain
Identical Mode	HIERARCH INS RESOL HIERARCH INS CENTRAL WL	Spectral Resolution (LOW, MED, HIGH) Central Wavelength
Identical Observation	Identical Readout + Identical Mode + HIERARCH TPL START HIERARCH FT STATUS HIERARCH NB TEL	 Starting date of observation (difference between calibrator and target should be less than xx hours) Fringe Tracker Status (NONE, TRACKING) Number of telescopes

SPICA-VIS Science operation (JMMC collaboration)

Database based on ObsPortal, OIDB, JSDC, ASPRO2 at JMMC

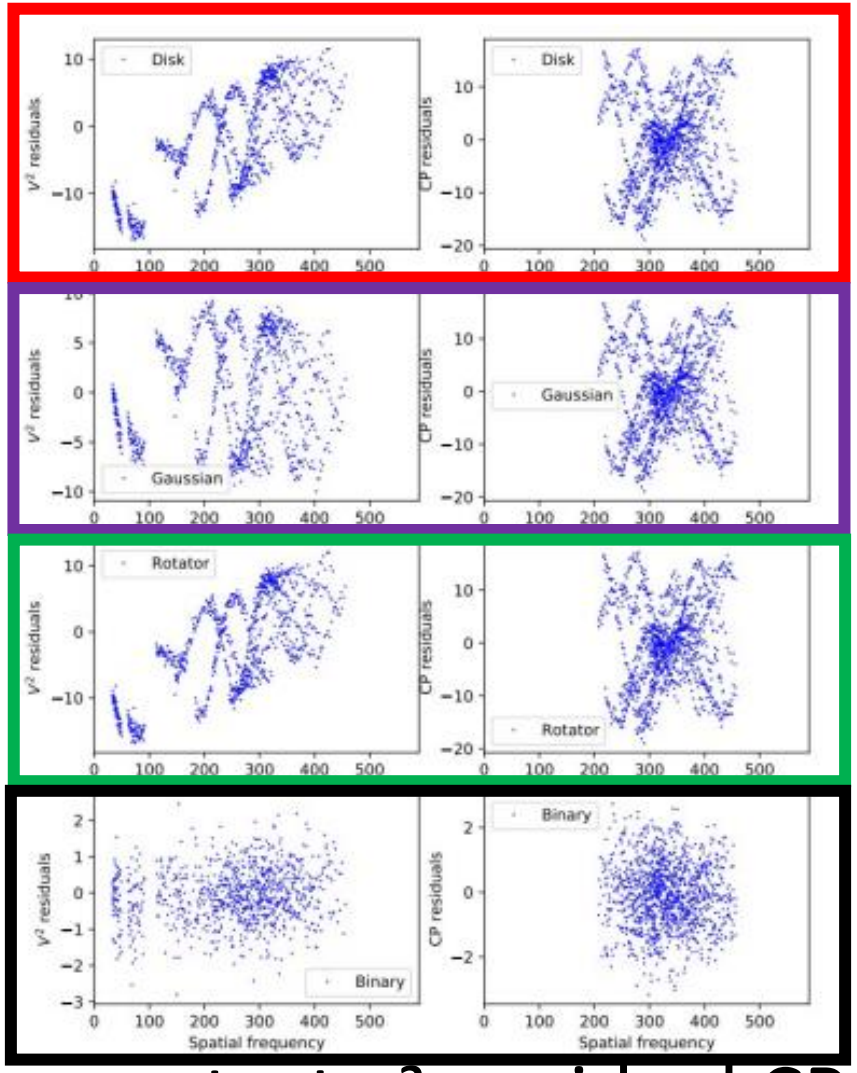


SPICA-VIS Quality Control

Automatic fit at the end of the night on all targets and calibrators. 4 models:

1. **Uniform disk**
2. **Uniform disk + gaussian**
3. **Elongated disk (fast rotators)**
4. **Binary using CANDID (Antoine Mérand)**

Computations made by D. Salabert, using ASPRO2 (SPICA) and the SPICA autofitting function.



residual V² residual CP

	A	B	C
1	OCS_UD_DIAM	0.373480	
2	OCS_UD_ERRDIAM	0.001192	
3	OCS_UD_REDCHI2	59.185	
4	OCS_UD_NBDOF	2099	
5	OCS_GAUSS_DIAM	0.343815	
6	OCS_GAUSS_ERRDIAM	0.002100	
7	OCS_GAUSS_FWHM	16.635100	
8	OCS_GAUSS_ERRFWHM	165135603805.865784	
9	OCS_GAUSS_FRATIO	0.064068	
10	OCS_GAUSS_ERRFRATIO	0.003919	
11	OCS_GAUSS_REDCHI2	47.330	
12	OCS_GAUSS_NBDOF	2097	
13	OCS_ROTATOR_MAJORDIAM	0.375595	
14	OCS_ROTATOR_ERRMAJORDIAM	0.002086	
15	OCS_ROTATOR_ELONG	1.012273	
16	OCS_ROTATOR_ERRELONG	0.010056	
17	OCS_ROTATOR_PA	75.102742	
18	OCS_ROTATOR_ERRPA	20.143640	
19	OCS_ROTATOR_REDCHI2	59.141	
20	OCS_ROTATOR_NBDOF	2097	
21	OCS_BINARY_DIAM1	0.350401	
22	OCS_BINARY_ERRDIAM1	0.000160	
23	OCS_BINARY_X	1.414643	
24	OCS_BINARY_ERRX	0.000448	
25	OCS_BINARY_Y	1.413492	
26	OCS_BINARY_ERRY	0.000441	
27	OCS_BINARY_FRATIO	4.890021	
28	OCS_BINARY_ERRFRATIO	0.013444	
29	OCS_BINARY_REDCHI2	0.823	

Database feeding

SPICA planning