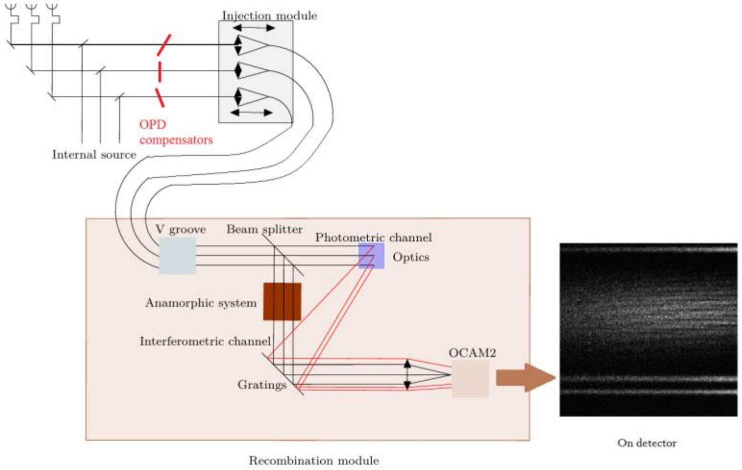
SPICA: a new visible combiner for CHARA

Signed by many colleagues!

Summary of the previous seasons

- 2012: VEGA limitations (intensified CCD+multispeckle) + Prospect on CHARA/AO + Progresses on EMCCD ➔ propositions P. Bério (FRIEND)

- 2013-2015: FRIEND development and tests
- 2015: first discussion at Atlanta
- 2016: Visible meeting after the CHARA Meeting



- 2016-2017: Definition of the SPICA proposal, funding request (5-year grant unsuccessful but local funding ok to start), project organization.

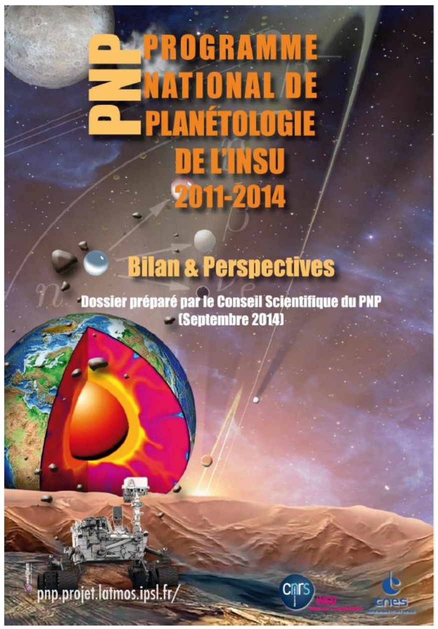
Conclusions of Visible day (Nice, 2016)

Today's main points of conclusion?

- Science
  - Imaging/spectral-imaging
  - High-efficient θ machine
    - ➔ Sensitivity (detector, AO, FT)
    - ➔ Simple instrument with integrated pipeline, very few modes (2-3 maximum)
- Concept
  - Technology ready
  - Bulk/IO: choice to be sensitivity-driven
  - Multi-axial, dispersed fringes
- Interfaces (important for sensitivity and reliability)
  - Pupil and image trackers, LDC
  - AO and fiber injection
  - NIR for group-delay/fringe tracker: residuals versus magnitude/r0/dispersion…
- Control/operation/DRS
  - To be built on previous experience (see JMC talk) and CHARA integrated
  - More automatic processes towards final products

Stellar Parameters and Images with a Cophased Array

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

SPICA science case

- Surface-brightness-color relations
- Masses
- Fundamental parameters as a function of SpTy
  - Radius
  - Effective Temperature
  - Limb darkening

➔FROM EMPIRICAL MODELS TO MEASURES

- Exoplanets host stars
- Asteroseismic targets

- Original and unique support to a large panel of space missions (Gaia, TESS, CHEOPS, PLATO) and unique support for stellar masses and stellar evolutionary constraints

White Book of P. Stee et al. 2015
50 co-authors, 134 pages

https://arxiv.org/abs/1703.02395

3 years * 70 nights = 1000 stars

- 1000 stars: 100* for spectral imaging, 200* binaries or multiple, 700* for FP
  - *5*100+10*200+2*700=3900 observations + calibrators ➔ 8000 data points*
  - *40 objects per night*
- 2015: 187n, 4699obj ➔16obj/n. Factor 2.5 missing

- But
  - AO ➔75% of 'good seeing' conditions
  - 6T means 15V²
  - Low spectral resolution, improved number of channels, λ-coverage
- Probably feasible:
  - PAVO/FLUOR experience of fast shift
  - Queue scheduling and optimization

SPICA: a first synthesis

- High-efficient θ/FP machine
  - ➔Sensitivity (detector, AO, FT), Efficiency (6T)
  - ➔Simple instrument with integrated pipeline
  - ➔R=100, 600-900nm
- Imaging/spectral-imaging
  - ➔R=3000 to preserve a good sensitivity
  - ➔6T
- R>30000 option for specific studies

A: a classical dispersed fringes (VEGA/MIRC/VISION) 6T
B: a more prospective HR, wide band design with Echelle Spectrograph 3-6T
C: a powerful Phase Tracker

Main points of attention

- **Sensitivity**
  - AO-Fiber coupling and V^2 optimization
  - Alignment control (pupil and image)
  - Simple design; choice of components, lab implementation
  - Bulk/IO choice
  - Exposure time: Group Delay – Phase tracking
- **Efficiency**
  - Fight against downtime and overheads
  - Instrument-Array interface optimization
  - Automatic execution of OB + optimized night scheduling ➔ $f(\alpha,\delta)$
  - 'integrated' pipeline

Two main drivers for performance

Detector

Nüvü512 ok for Mode A, 6T, low noise, fast readout

Nüvü1024 ok for Mode B, 3T, ~20 orders, R=30000 & $\Delta\lambda$=200nm + Phase Tracker #1

IR detector for Phase Tracker *(Selex?)*

Phase Tracker

Group Delay is mandatory

Phase Tracker #1: DIT=200ms, $\lambda/10$ (60nm)

Phase Tracker #2: DIT=30s, $\lambda/4$ (150nm)

➔Gravity like FT

➔ IR versus Visible

A: LR/MR with Group Delay
B: HR
C: Phase Tracker

Expected performance (1)

- Based on VEGA/CHARA + FRIEND experience
- S/N (V^2) equation comes from Gordon&Busher 2012 (eq.28)

- Numerical hypothesis
  - Tinst=0.01; T-AO=0.8; SR=0.25; Coupling=0.2 ; Vinst=0.9
  - QE=0.9, RON=0.1, Ndark=0.0002 (NUVU)

Expected performance (2)

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

	R=100	R=3000
V^2=0.25	**8.7**	**5.0**
V^2=0.01	**5.6**	**1.9**

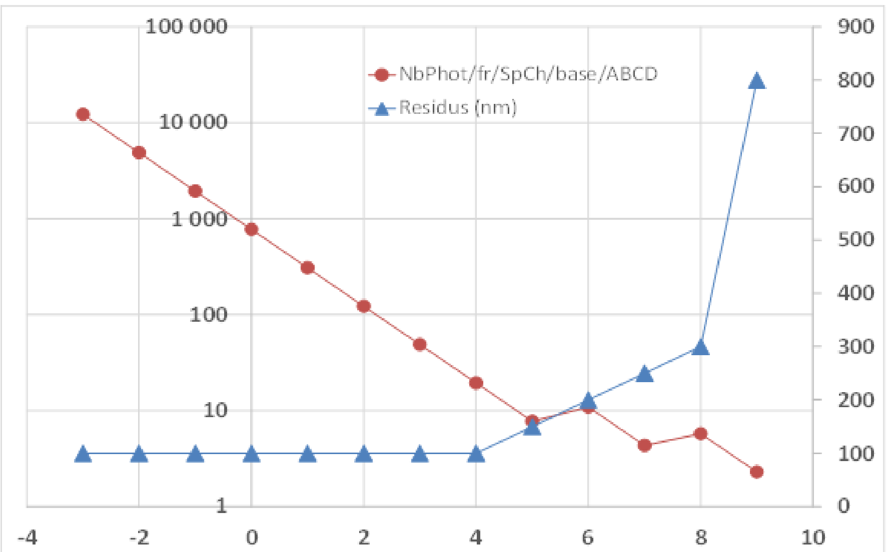
Table 1: Limiting magnitude with a group delay tracker only

	R=100	R=3000
V^2=0.25, DIT=0.2s	**10.1**	**6.4**
V^2=0.25, DIT=30s	**11.4**	**7.7**
V^2=0.01, DIT=0.2s	**6.7**	**3.0**
V^2=0.01, DIT=30s	**8.0**	**4.3**

Table 2: Limiting magnitude with a phase tracker

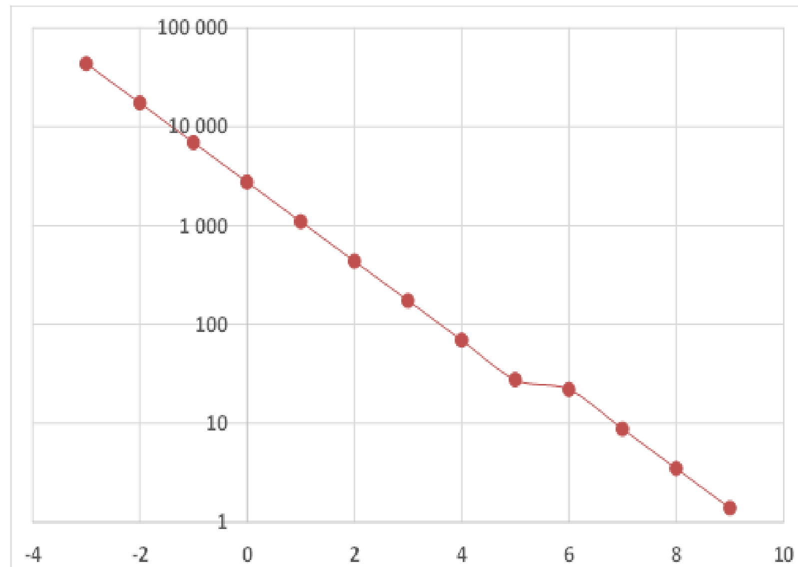
These estimations use the same S/N calculator of FRIEND, validated on-sky

Estimation of performance for a H-band CHARA FT



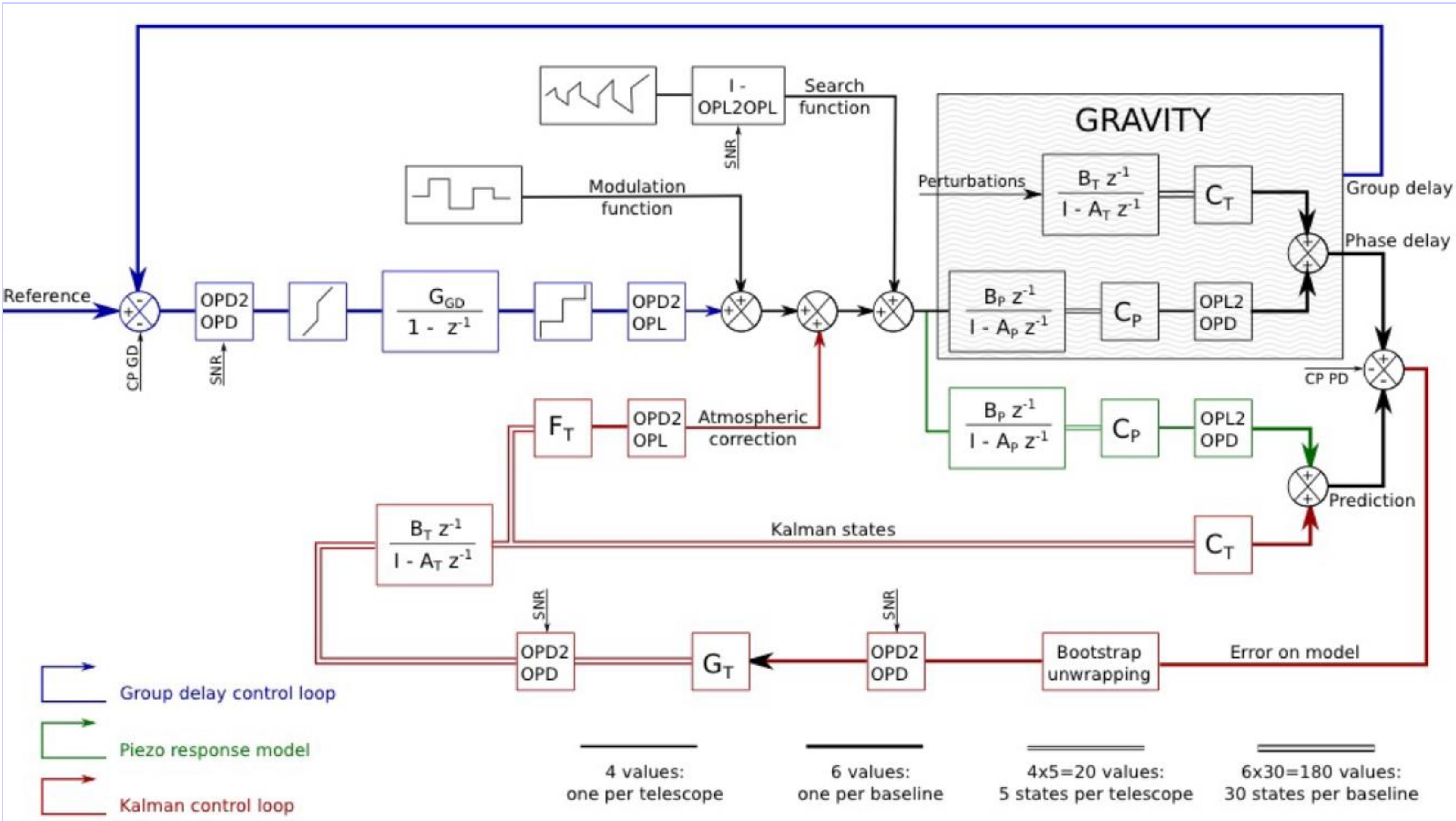
VLTI-GRAVITY FT performance

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

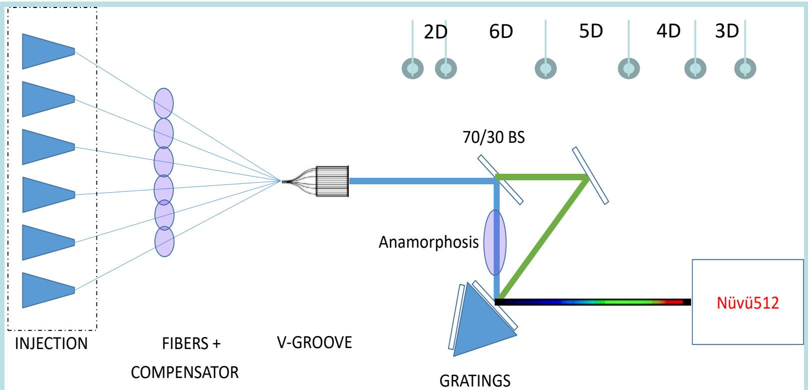


Adaptation of MIRC? New system? TBD…

GRAVITY State machine. © S. Lacour



Instrumental principle of SPICA

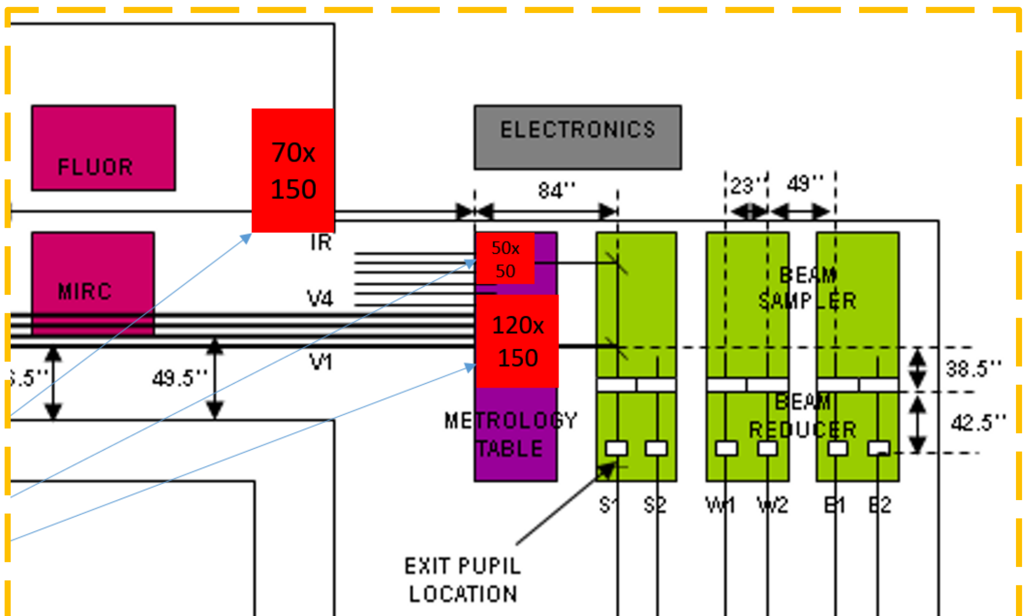


- ❑ Pickup optics: principle of PAVO dichroics
- ❑ Parabola + fibers + Birefringence
- ❑ Retro-feed of fibers for alignment (Pup+Im)
- ❑ Extraction of photometry
- ❑ Access to CHARA sources for daytime alignment
- ❑ FRIEND-like

Combiner+Detectors

Infrared injection?

Visible injection



Work breakdown (1)

1. **Pre-studies on critical components**
   1. Nuvu qualification + software control
   2. Evaluation of new actuators
   3. LDC check : do we need them? new glass for improved transmission?

2. **Studies on critical conceptual aspects**
   1. FRIEND fibers + OA injection : additional tip/tilt? Retro-lightening and direct co-alignment with CHARA?
   2. Principles for photometry extraction: pupil slicers, flux slicers, see possibilities after the fiber exit.
   3. Monitoring of seeing parameters : r0, t0

Work Breakdown (2)

3. **Science requirements and performance evaluation**
    1. FRIEND S/N values + all FRIEND parameters : SPICA S/N calculations and performance evaluation
    2. Decision on spectral resolutions
    3. Definition of observing modes
    4. SPICA large program science group organization

4. **Fringe-tracking**
    1. Design of a H-band fringe tracker optimized in terms of transmission, number of spectral channels, detector and all parameters.
    2. Continuation of performance evaluation

Work Breakdown (3)

5. **Optical and mechanical implantation**
    1. Pupils position, OPD scheme
    2. Optical design and implementation
    3. List of optical pieces, list of mechanical pieces, list of motors and actuators
    4. How to accommodate a high spectral resolution mode: number of beams, 2nd detector
    5. Alignment procedure, operating procedure

6. **Software architecture** :
    1. ICS FTS DCS OS
    2. Data flow of acquisition and archiving : database L0
    3. Data flow of DRS and RT-DRS : policy for L1 and L2
    4. Specifications of RT-DRS
    5. Specifications of quality check, database of quality check
    6. Automatic pipeline
    7. Operation software : queue observations, calibrator sequence

Short term activities

Continue to acquire experience with FRIEND prototype (especially AO/injection and piston)

Nuvu512 qualification/acquisition

System analysis ➔ specifications.

Implementation in the lab, general design of science light path and control systems

Funding mid-2017 ? ➔ 1st light mid-2019 (A), 2020 (B+C)