# Precision Integrated Optics Near-Infrared Experiment

**Le Bouquin, Berger**, Zins, Lazareff, Traub, Jocou, Kern, Haguenauer, Absil, Augereau, Benisty, Blind, Bonfils, Delboulbe, Feautrier, Germain, Gitton, Labeye, Lizon, Monin, Magnard, Malbet, Maurel, Menard, Micallef, Michaud, Montagnier, Morel, Moulin, Perraut, Popovic, Rabou, Rochat, Roussel, Roux, Stadler, Tatulli, Ventura...

+ CRISTAL and FOST teams from IPAG + ESO

# First idea of “PIONIER” …

From 2002 and 2003, ESO and IPAG collaborated for the 2-telescope test-instrument VINCI. Further discussions lead to this proposition:

**Karine Perraut <kperraut@obs.ujf-grenoble.fr>** 22 Jun 2003 17:58
To: Jean-Baptiste Le Bouquin <Jean-Baptiste.Lebouquin@obs.ujf-grenoble.fr>, malbet@obs.ujf-grenoble.fr, Pierre Kern <kern@obs.ujf-grenoble.fr>, Karine Perraut <kperraut@obs.ujf-grenoble.fr>, Pierre Labeye <Pierre.Labeye@cea.fr>, Jean-Philippe Berger
Hide Details
autrePionier

Compte-rendu - Reunion VLTI-4T

```
On propose a l'ESO de realiser un VINCI ++ avec les caractéristiques suivantes :
  + recombinaison de 4 telescopes
  + fonctionnement en bande H
  + capacite de faible dispersion spectrale (type prisme)
  + un coaxial 4T par paire sans voies photometriques
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Then the idea get lost for about 6 years…

… so let’s jump directly to 2009.

# Context in 2009

**General**

- OLBIN enters the era of imaging instrument
- The game is mainly in the US with CHARA/MIRC.
- Current sensitivity cannot reach YSO

**At VLTI**

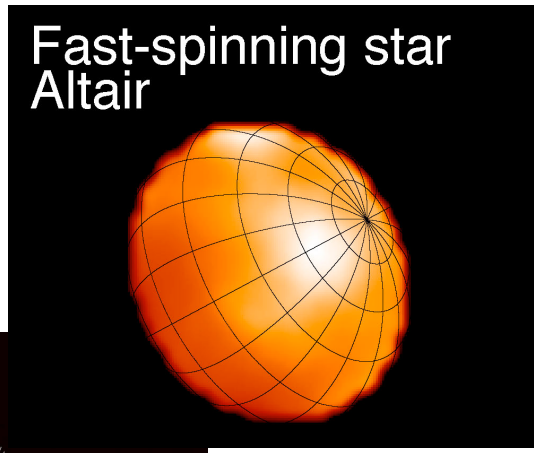
- Successful ESO / IPAG collaboration on VINCI
- Working better and better !!
- 4 telescopes already available since 2007
- Next-generation projects planned for 2014 (GRAVITY and MATISSE)

**At IPAG**

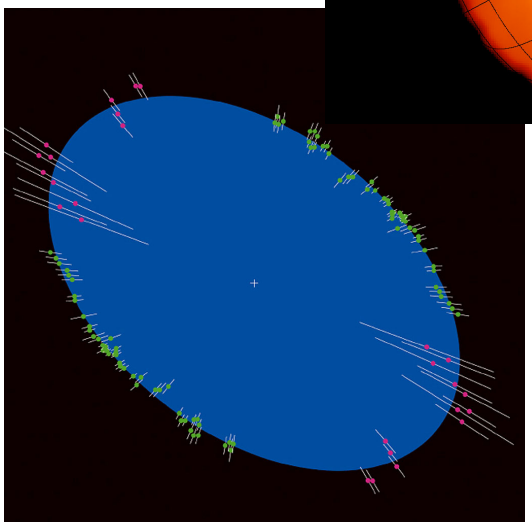
- Expertise and interest in imaging interferometry
- Difficulties to run some projects with AMBER/MIDI (T-Tauri, exozodial disks, faint companions)
- 4 telescopes IONIC beam combiner available on-the-shelve: a result from several years of R&D

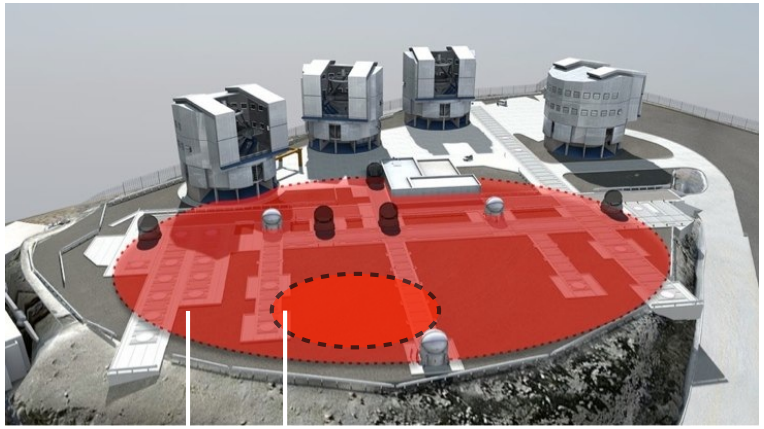
**Need for a fast project to catch-up competition!!**

CHARA




VLTI





# The proposition to ESO

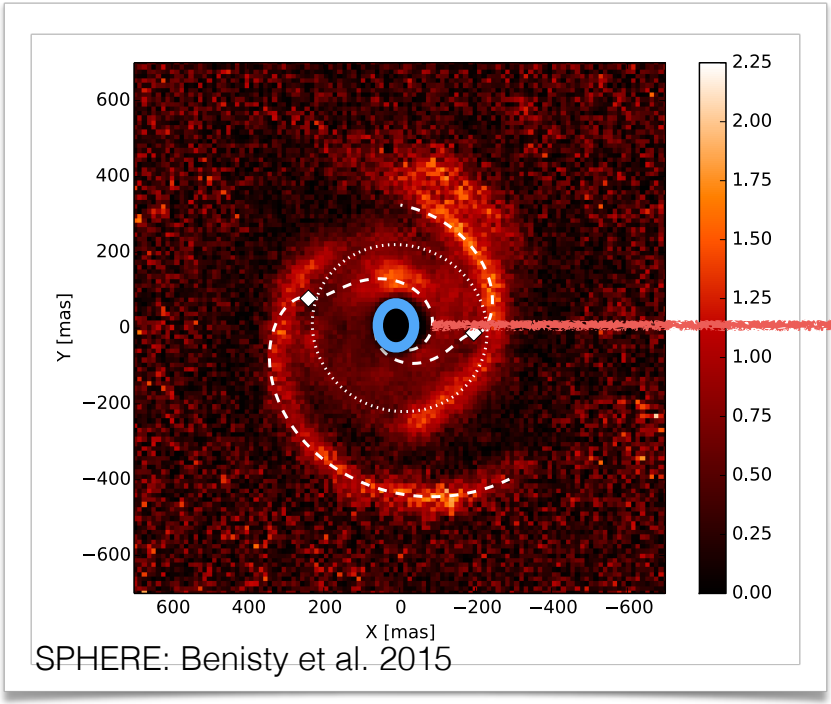
**Proposition made in 2009 by IPAG to ESO**

- Build an instrument to combine the light of 4 telescopes of VLTI, using the visitor-instrument framework.
- On sky by end of 2010, with few days of commissioning.
- Exploit this instrument with few weeks per semester over the 2011-2013 period.

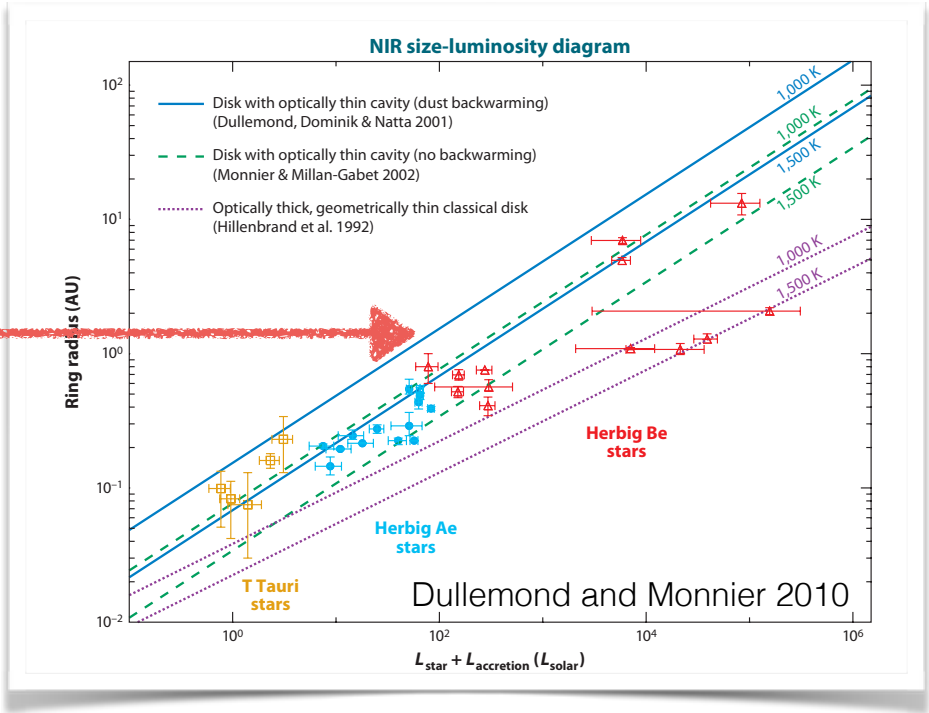
**Initial funding and collaboration**

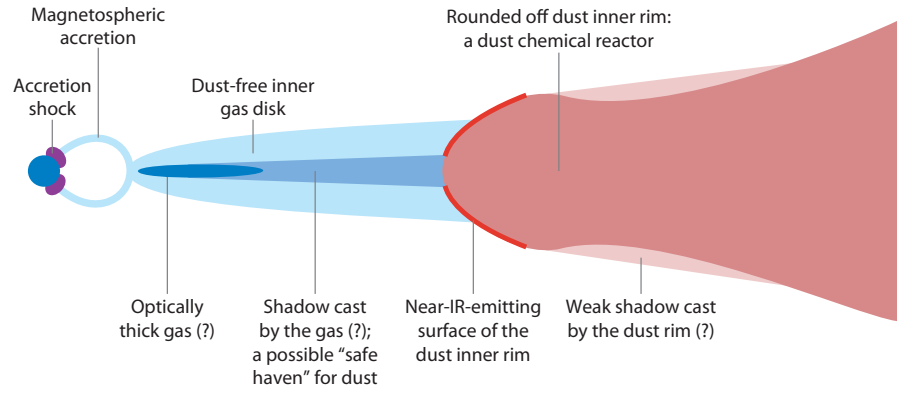
- First: Local funding (University), bring most of the money ~150k€
- And then national support (CNRS, ANR) for operations ~50k€
- IPAG + W. Traub / R. Millan-Gabet (IOTA infrared detector)
- Critical ESO contribution: administration, shipping, travels, technology sharing, fluids…

# Science case : YSO



SPHERE: Benisty et al. 2015




What is the structure of protoplanetary disks inner astronomical units?

# Communication

**PARANAL: System Engineering**

- Is there interest on Paranal side (2nd gen)?
- Is the timeline (fast track) and workload acceptable by director
- What are the interfaces?

**French Community:**

- IPAG directorate
- Head of INSU: **OK but don't ask for money**
- ASHRA (french high angular resolution scientific council): de-mining
- University of Grenoble funding + science programs

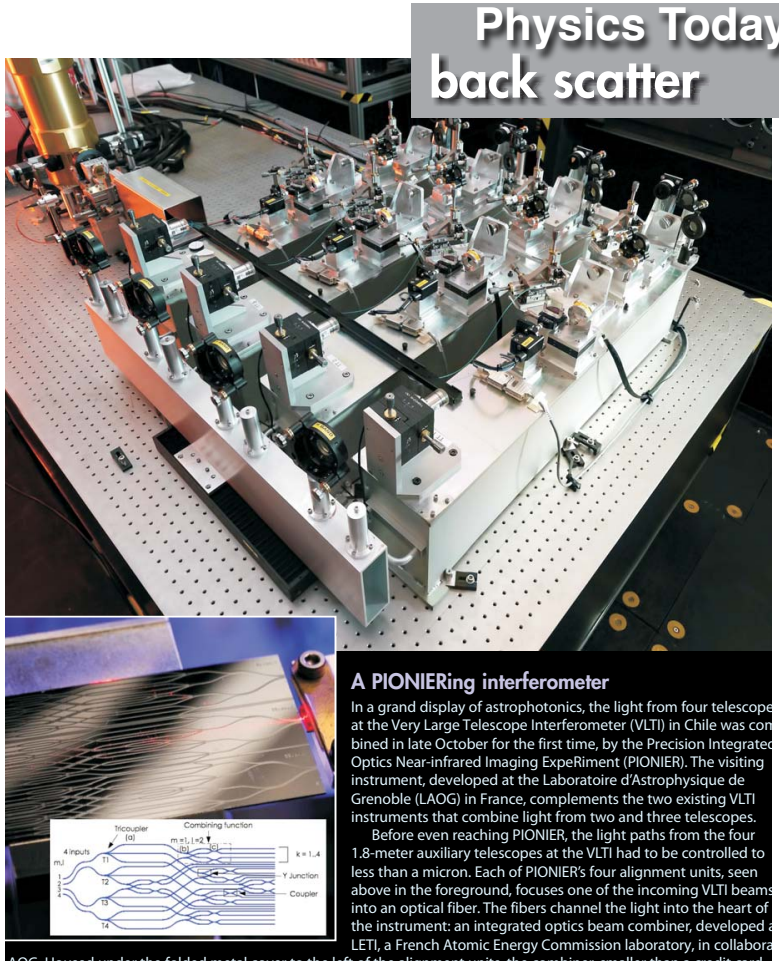
**ESO Garching:**

- Presentation of scientific project to VLTI team
- Meeting with Director of programs ➔ DG ➔ Greenlight to go to LSP with proposal
- Meeting with Y. Mellier (STC chair)
- Submission of science/technical proposal to LSP april 2009: green light
- **Submission of "pre" science proposals to OPC P84** (in agreement with ESO directorate of science

**Community**

Search for collaborations within Europe (detector): did not work

# Project size overview




PIONIER installed at the focus of VLTI as of 2010

**Simple hardware / software:**

- Single scientific mode
- IR Camera on loan from JPL (USA).
- About 80% is VLT-standard.
- Limited number of motorised functions.
- One internal real-time 500Hz loop

**Project management:**

- Single site manufacturing / integration, few interfaces except ESO
- Project duration ~2 years
- Hardware cost : 200 k€
- About 6 FTE involved at IPAG
- Total consolidated cost : 700 k€

Project-management by G. Zins (great !)

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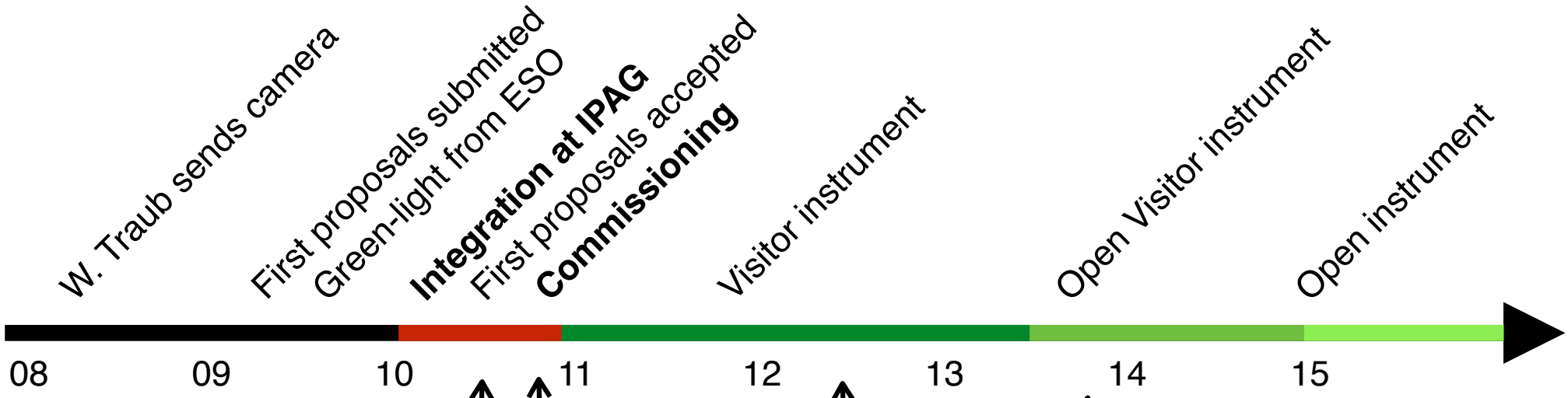
# A short but realistic schedule




**Such short schedule allows:**

- Full availability of people.
- Fast (but conservative) decisions, focus on solving problems.

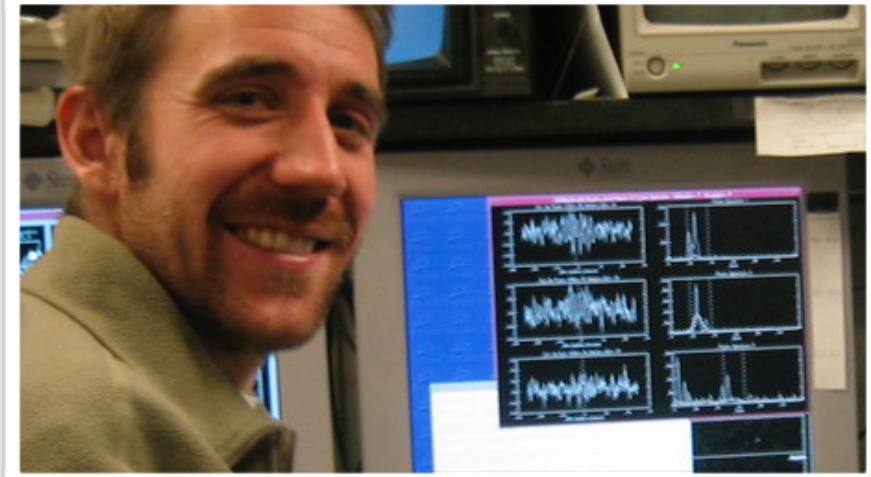
Date of “first light” was firmly known when the integration started.

~2 years to reach ultimate performances thanks to simple but frequent updates in operations.

PIONIER became the most requested instrument of VLTI, thus ESO opened it gradually

# A balance between heritage and innovation

## IOTA 2002



**Heritage from 10 years of research:**

- Mature technology: 4-telescope integrated optics component from research in instrumentation (CNRS, ANR) at IPAG.
- Instrumental concept (scanned fringes) experienced by the team in FLUOR, VINCI, IONIC-3.
- DRS concepts well established.

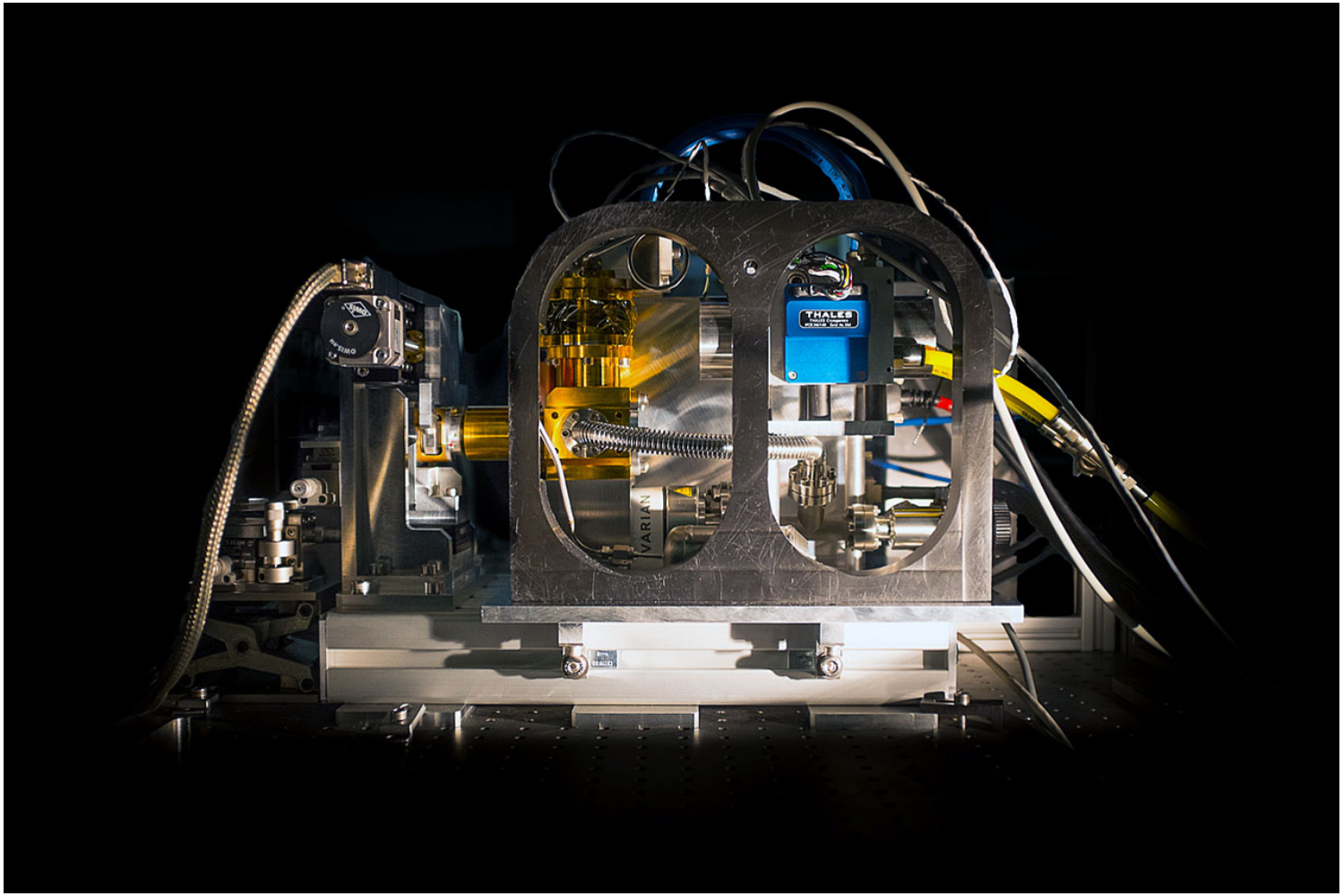
## VLTI 2010

**Innovations:**

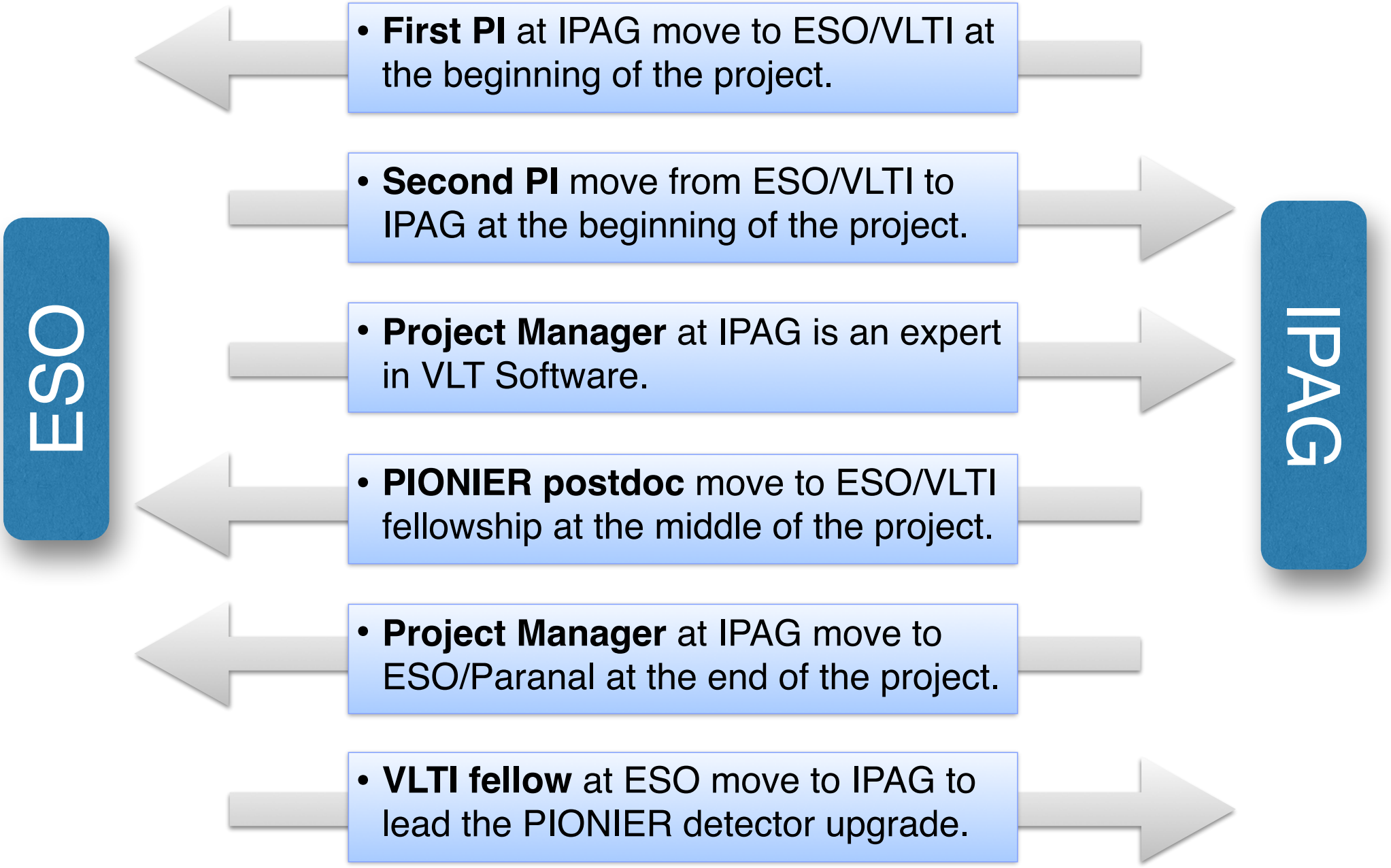
- First 4-telescope combination of VLTI.
- Novel polarisation control.
- First use of cheap industrial PLC BECKHOFF in ESO instrument (instead of costly LCU)

# The RAPID camera

FIRST APD IR camera on sky (SOFRADIR)



# Is PIONIER really a “visitor” instrument ?

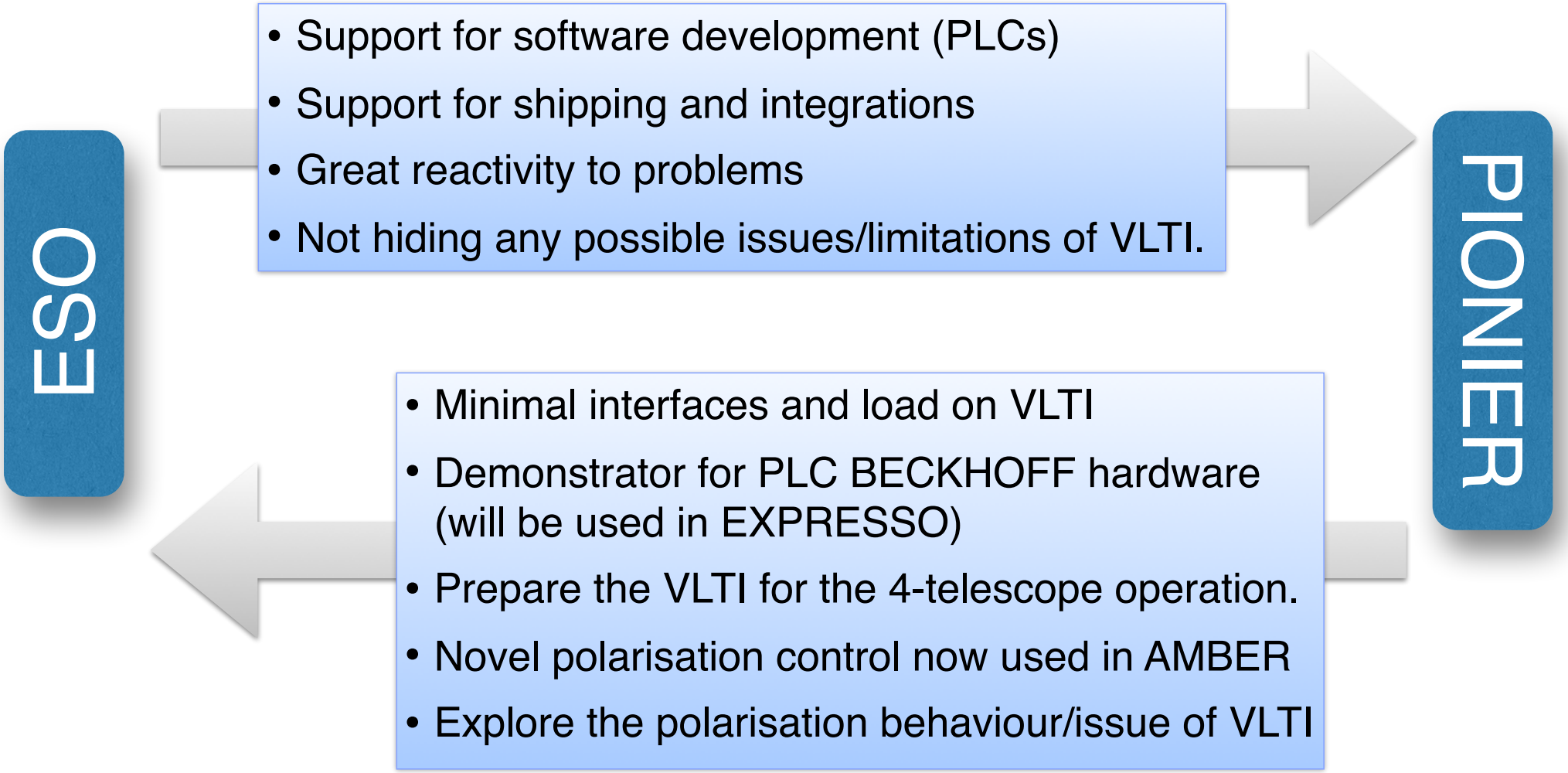


# Interaction Consortium-ESO

- SoW defining relationships between ESO and the Consortium
- No real consortium: project managed and achieved by IPAG
- No formal review: continuously and closely monitored in relation with ESO
- ESO included in project as partner
- Documentation limited to critical points; ICD, safety and operations.

- Mutual trust from Paranal to the Consortium, allowing non-standard solution (ex: install the electronic cabinet inside the VLTI lab).
- Even if the rules and standard procedures were always tried to be fulfilled, all partners keep a pragmatic approach.

# Interaction Consortium-ESO

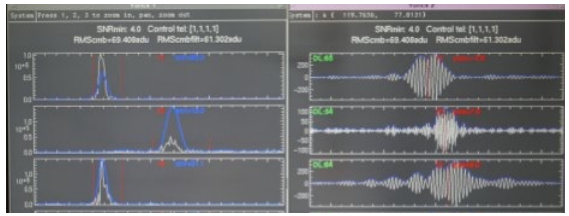


# Fast-track success-oriented project

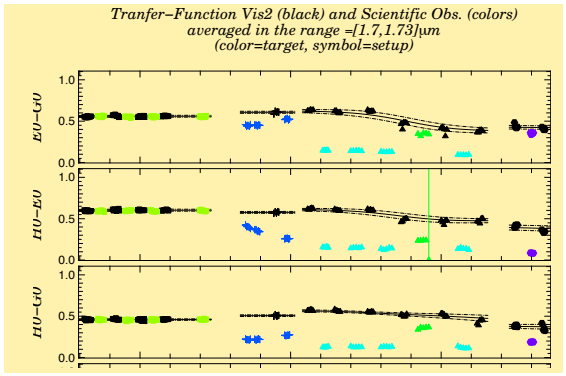
- Hardware was **already existing** for critical sub-systems.
- **Simultaneous** request for funding, request to ESO, order first items, OPC proposals, build science team…
- Focus on a small number of science cases, thus a **single instrument mode** that drive all choices between preliminary → final design → implementation.
- Favour solutions with operational experience, because developing an **operational experience** is costly in time and manpower.
- Gather a “system view” of **both the visitor instrument and the host VLTI**, to make strategic trade-off considering the global picture.

PIONIER is the most sensitive instrument of VLTI while it is the cheapest, the quickest, and the less optimised in many aspects.

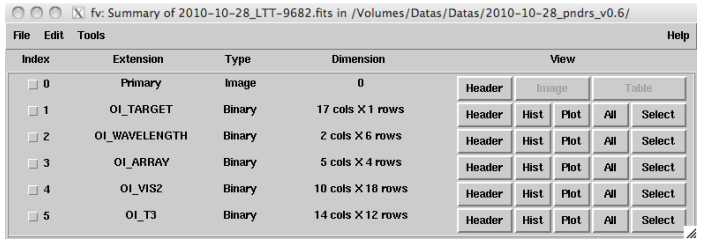
# Data reduction/delivery



RAW data




Night trending and global calibration

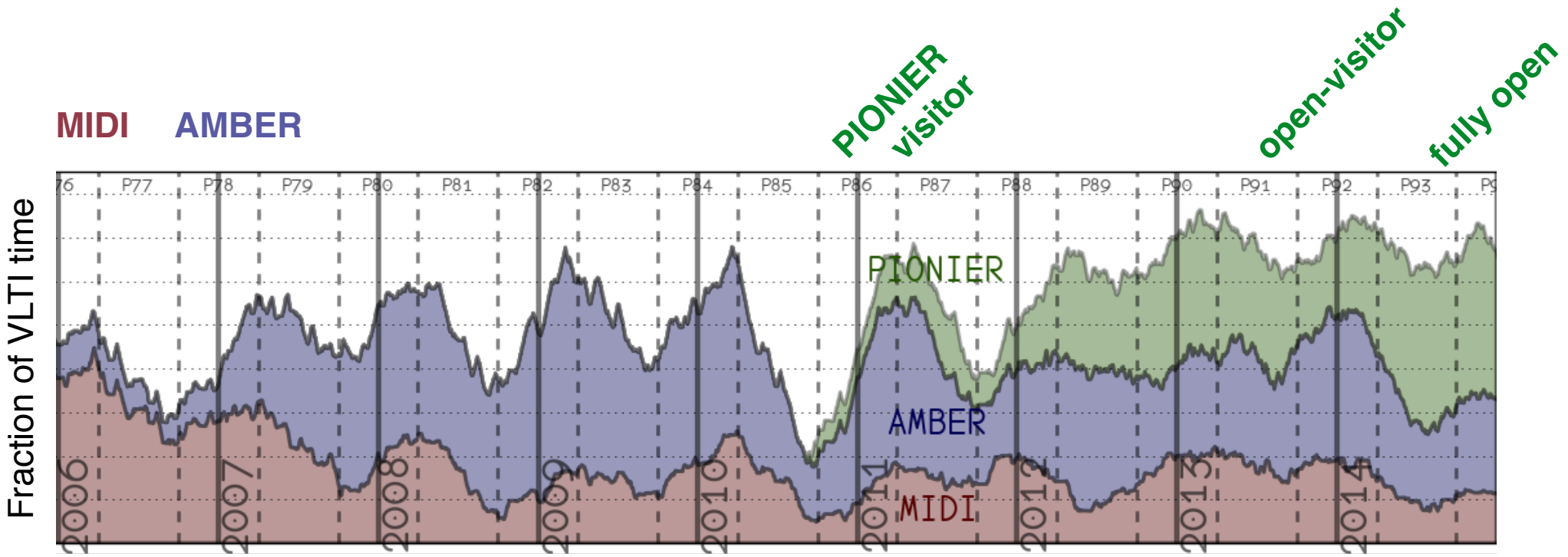



Science ready OI-FITS

- DRS is non-standard (python like)
- DRS evolved during about 2 years to reach best performances (+1mag in sensitivity).
- Fairly easy (1 man-week) to interface it with the ESO pipeline system, because **DRS follows the ESO/recipe logic** as well.
- Support from the consortium may be needed if major upgrade of the instrument.

- PIONIER is the first VLTI instrument to produce **immediate science-ready products, with absolute calibration**.
- Available to the PI in a global archive, and to the whole community after 1 year.

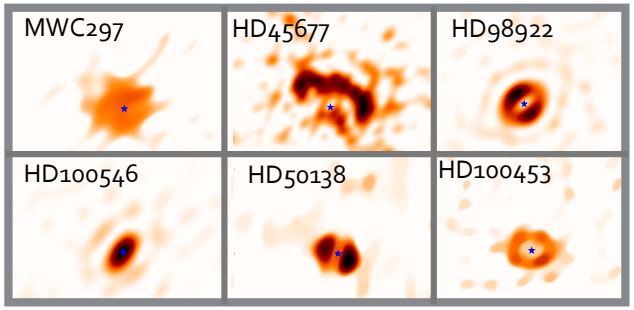
# Observing modes and GTO

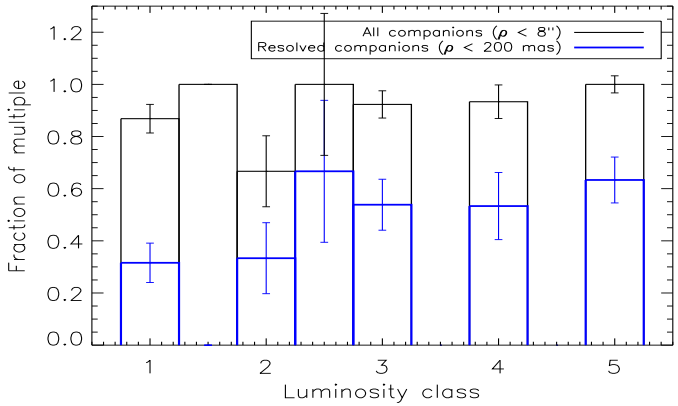


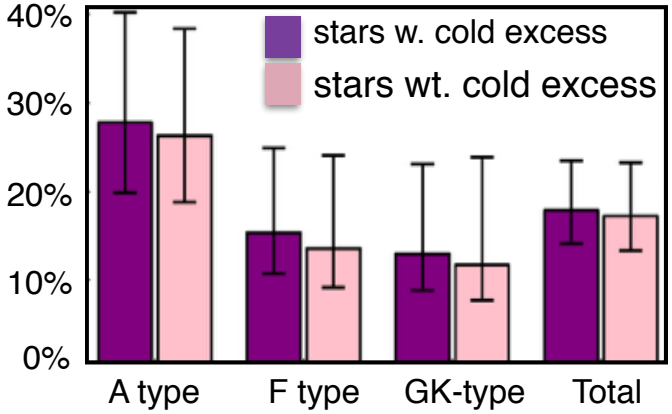

- No GTO, open-time proposals only.
- Instrument access restricted to the consortium (visitor instrument).
- Huge load on the consortium (>12 travels / year)
- Question: how to assess the feasibility of proposals by ESO ?

- Instrument now open to the community. Consortium compensated by ~3n/semester of technical time to try new ideas and push the instrument.

# Lesson learnt from Science



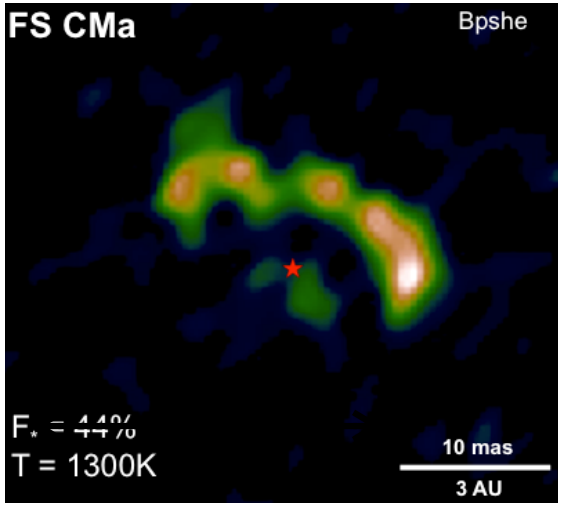



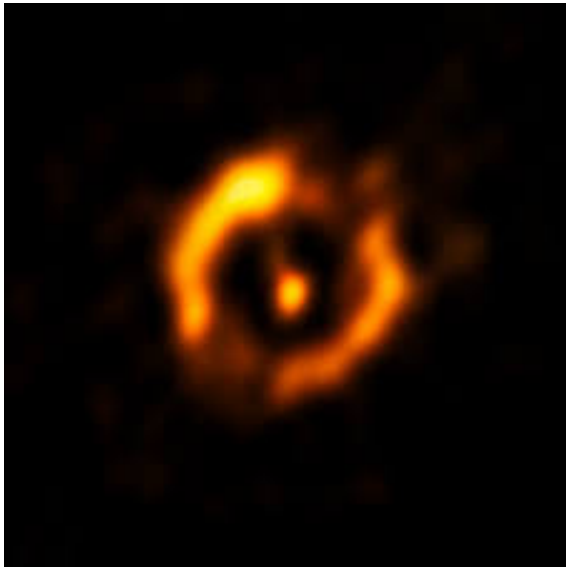

- PIONIER / VLTI reached the expected performances when proposing the instrument.
- 45 A&A and ApJ papers.
- Science productivity largely **enhanced by PIs outside the initial core-team**.
- Simple, reactive instrument makes best use of good atmospheric conditions slots.
- **95% of the science done with the ATs**

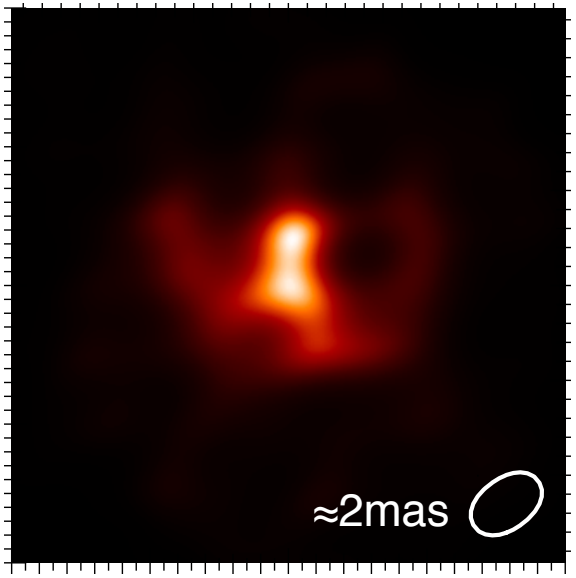
**Large program approach** :

- Survey >40 YSO to study the structure of the proto-planetary disks.
- Survey >100 O type stars for multiplicity.
- Survey >200 main-sequence to search for exozodiacal dust.

# Imaging at mas resolution…

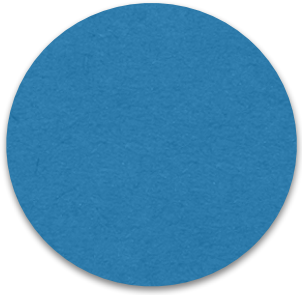


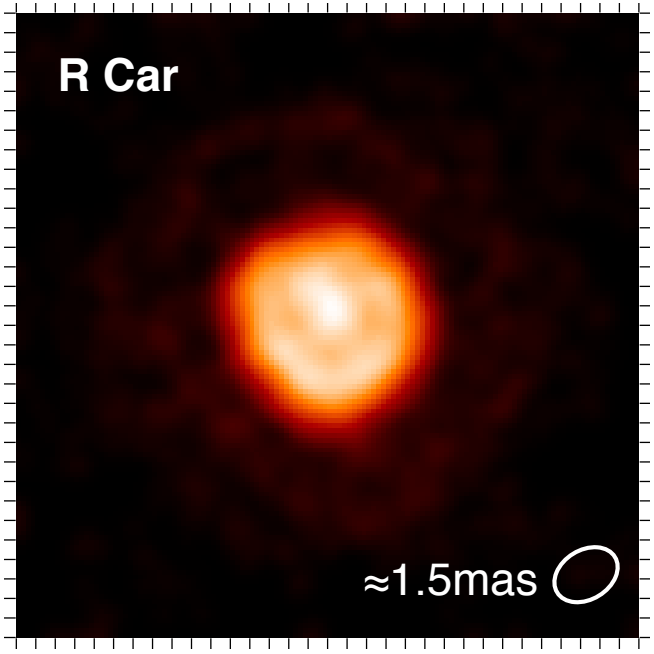



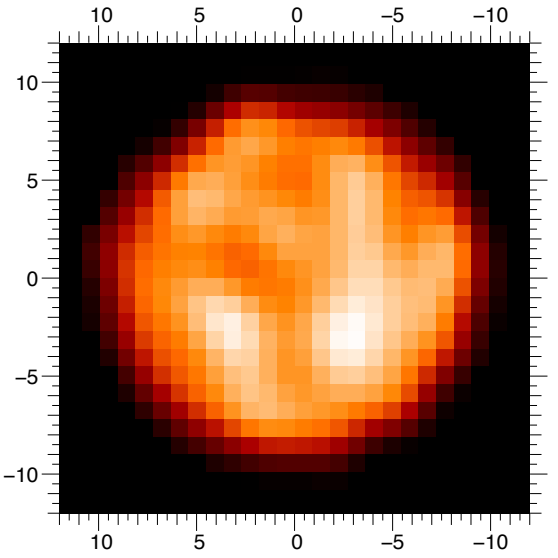



*±1500 AU*

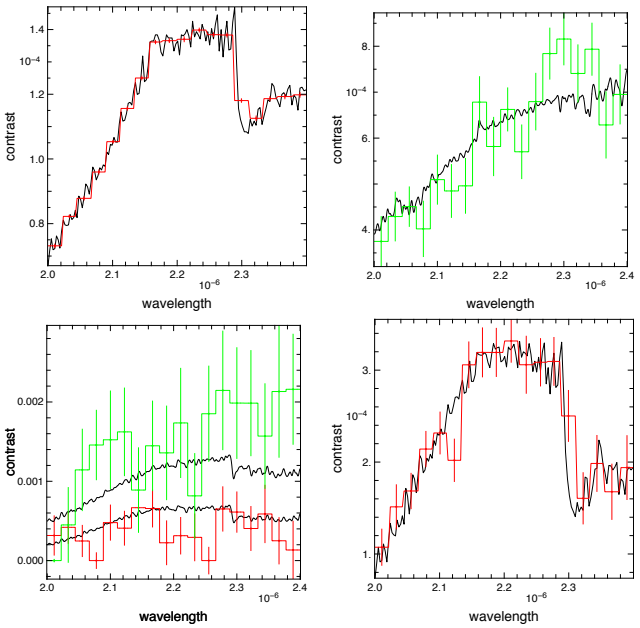
SPHERE PSF-size
(Zimpol)



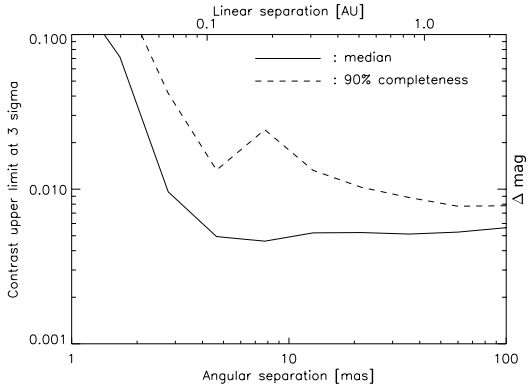


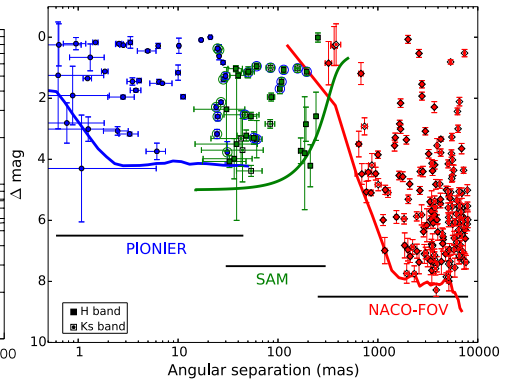
# A few words on high dynamical range




Renard et al. 2008



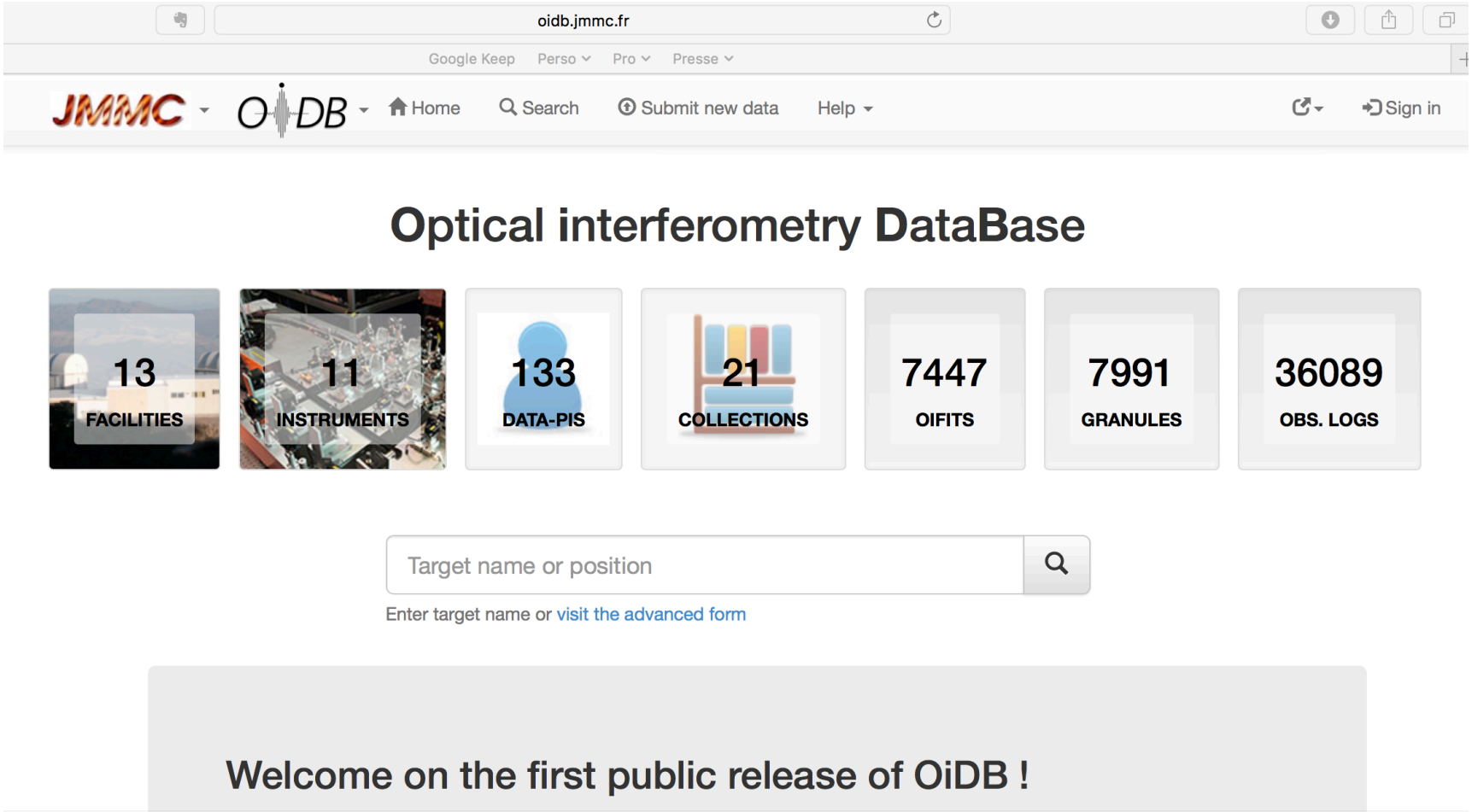

Absil et al.




Sana et al. 200

- PIONIER was never meant to be a high contrast instrument however …
  - Technically (read noise + photon noise) cp detection of hot jupiters (including spectra in some cases) was possible (UTS)
  - All detector reads were recorded for later fine data extraction (correlation)
- Closure phase precision (~0.5 degrees on bright targets) not sufficient to reach planetary levels.
- The “degree” (0.1-1deg) barrier in absolute CP difficult to overcome. Need a much better understanding of systematics (polarisation, piston).
- Differential quantities not fully exploited yet

# All the data is reduced and available



# General lesson learnt ?

- “Perfect match” in timing, motivation and expertise.
- Mutual trust and knowledge ESO / consortium based on previous collaboration and staff exchange.
- Consortium truly science driven, not “technical demonstrator” driven.
- The consortium interest was pushing in the nominal direction for ESO (no conflict of interest).
- Software/control experts motivated by the flexibility that allows to test new technologies in collaboration with ESO experts.

- Pragmatic approach on both ESO and consortium side.
- A balance between experience and innovation, with strong emphasis on robustness.
- Operational expertise was very beneficial in all steps (hardware, software, DRS).
- Attracting and getting help from super-experts was critical.