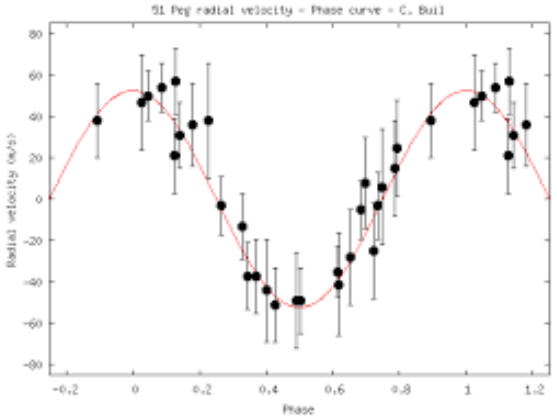
Contexte en évolution et enjeux technologiques pour la caractérisation d'exoplanètes depuis l'espace

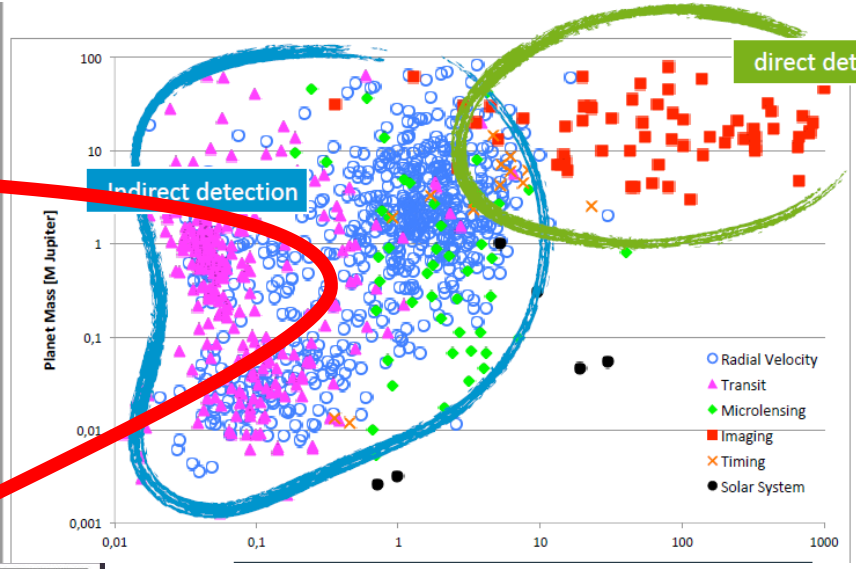
Eléments de contexte internationaux

- US decadal survey
- ESA Voyage 2050

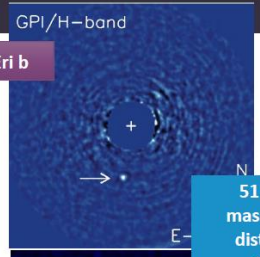
… et les travaux de structuration en cours :

- "Optimal Exoplanet Imagers" workshop *(Leiden, Feb 2023)*
- Presentation to ESA Science and Tech directorate *(Noordwijk, May 30th)* ; workshop en préparation 2024.
- US GOMAP
- France, concertation HWO-LIFE : CNES, SF2A

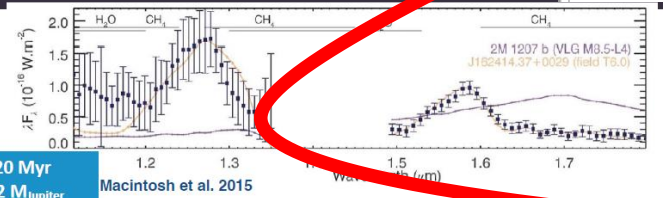


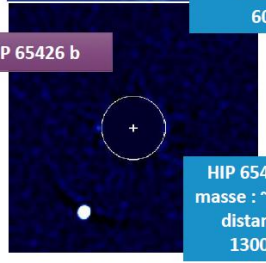


Direct detection and atmosphere characterization

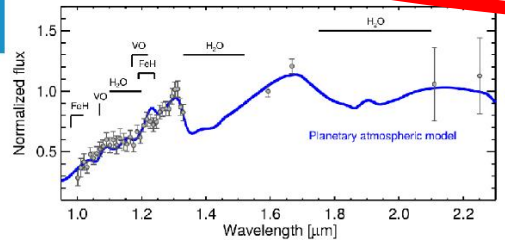


51 Eri : 20 Myr
masse : ~2 $M_{Jupiter}$
distance : 14 AU
600 - 750 K





HIP 65426 : 17 Myr
masse : ~ 6 -12 $M_{Jupiter}$
distance : 92 AU
1300 - 1600 K

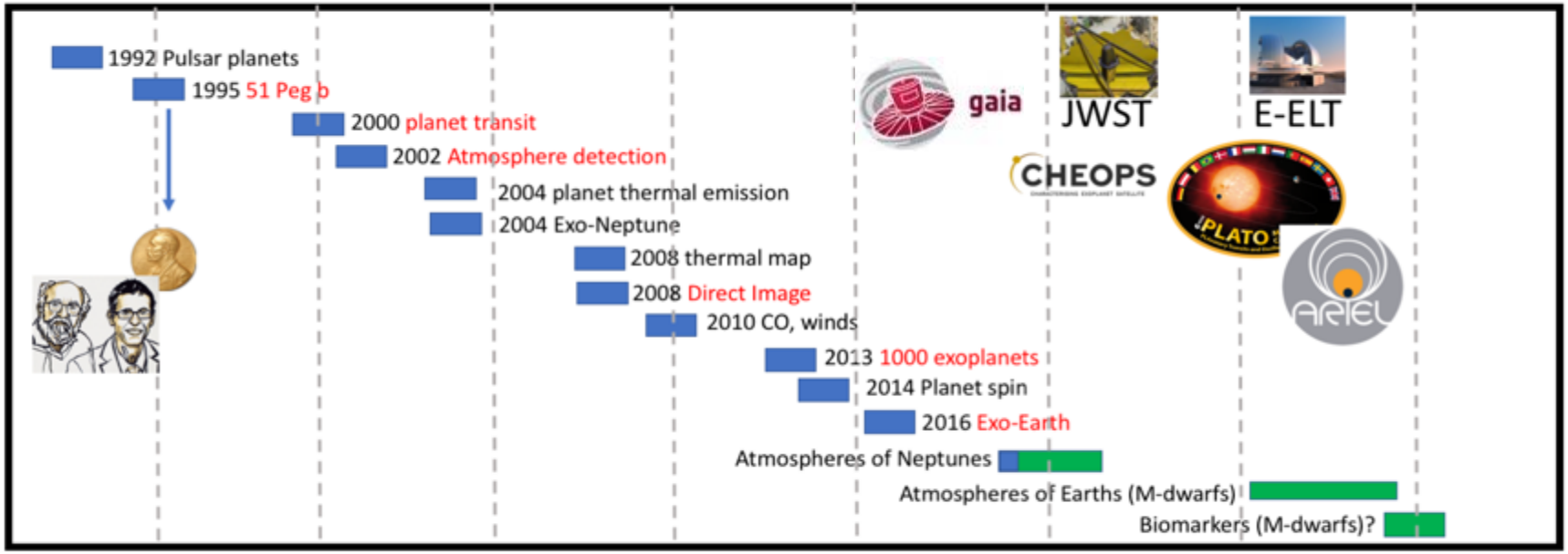


Towards telluric temperate planets

Both reflected and emitted light

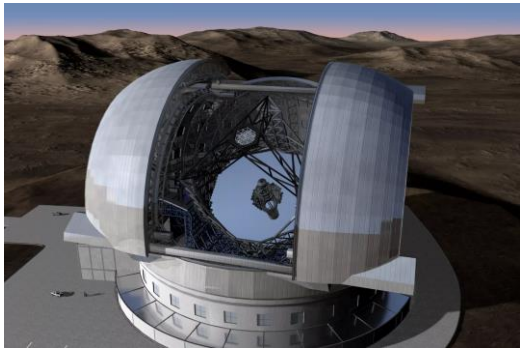
Fine characterisation (spectral, high SNR, polar)

A Revolution in Exoplanet Research (European perspective)

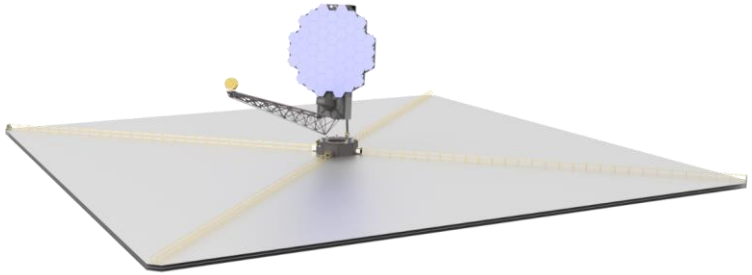


Complementarity **HCI ground** vs **HCI space**

from ground



from space



Scientific complementarity:

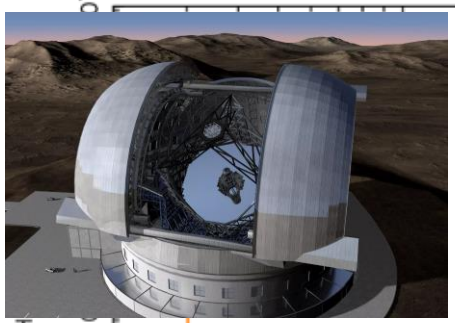
Better angular resolution → HZ around M-dwarves

Deeper contrast → HZ around solar-type stars
Broader bandwidth → finer spectral coverage and characterization

Commonalities and synergies:

- common **community**
- **scientific preparation** (targets, spectra, interaction with disks, dynamics, …)
- **system analysis:** WFS&C, (auto-)calibration, **extreme adaptive optics**, post-processing, novel stability and optical specs, integrated optics, detectors

Complementarity **HCI ground** vs **HCI space**



(2) Coronagraphy + differential techniques

Limited raw contrast (short perturbation timescales)

Great collecting area, and angular resolution

- Highly coupled system analysis
- Novel technological and demonstration challenges

(3) Ultimate on-board contrast

Pushing to extreme and stable contrast close to diffraction limit !

No atmospheric constraints (transmission, variabilty)

Complementarity **UV-NIR** vs **MIR**

From Quanz presentation Voyage2050

Scientific complementarity:

albedo, polarization, hazes/clouds, shortest separations ⟺ thermal probing, integrated atmosphere, different molecules

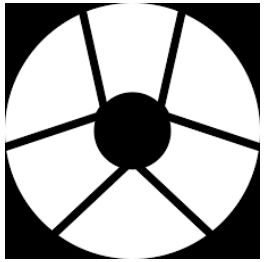
Commonalities and synergies:

- common **community**
- **scientific preparation** (targets, spectra, interaction with disks, dynamics, …)
- **system analysis**: WFS&C, (auto-)calibration, nulling/coronagraphy error budgets and tolerancing, post-processing, novel stability and optical specs, integrated optics, detectors

Programmatic context: next steps ?

NANCY GRACE ROMAN SPACE TELESCOPE

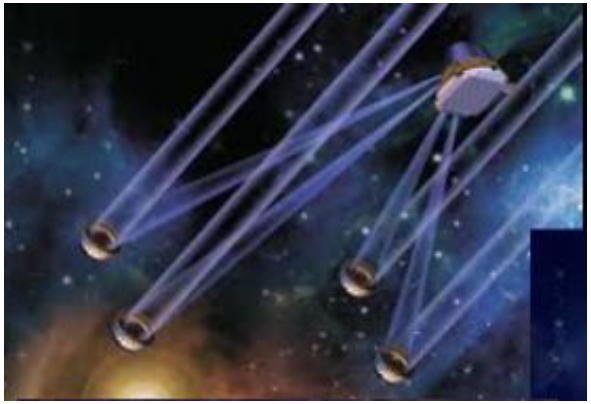
2-DM wavefront control for high contrast demonstration (on an unfriendly pupil)



LIFE

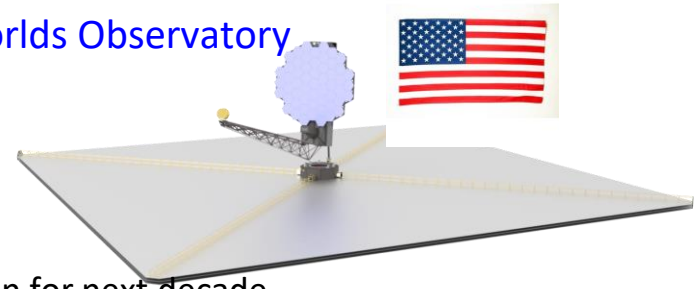
Voyage2050, Quanz et al

\+ Life collaboration paper serie



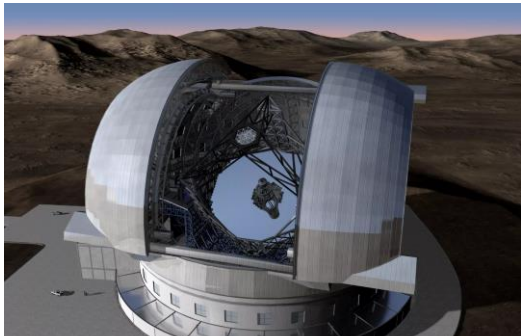
Long term programmatic plan
TO BE PREPARED NOW

HabWorlds Observatory



Mission for next decade

While high contrast is an important part of **ELTs** on the ground



Missions, technology, roadmap

need to organize on long-term scales

Programmatic aspects:

- ESA will issue its **“Long Term Plan”** in November this year
- Exoplanet characterization strongly present in Voyage2050 survey
  - characterization in the mid-infrared *(Senior Committee Report)*
  - possible European contribution to HWO for an instrument

Techno maturation activities

- HWO drives techno maturation by 2029
- Possible contributions rely on demonstrated expertises
- Contacts desired at various levels *(ESA, national agencies, coll.)*

CNES prospective starting !

community invited to express interest by October 1st

ESA poll for emerging techno

WITSO workshop Nov 2023

Dedicated workshop on high contrast early 2024 ?

Missions, technology, roadmap

need to organize on long-term scales

Eléments de contexte internationaux

- US decadal survey
- ESA Voyage 2050

… et les travaux de structuration en cours :

- “Optimal Exoplanet Imagers” workshop *(Leiden, Feb 2023)*
- Presentation to ESA Science and Tech directorate *(Noordwijk, May 30th)* ; workshop en préparation 2024.
- US GOMAP
- **France, concertation HWO-LIFE : CNES, SF2A**

Multi-labs (> 30 proposants) message à prospective CNES

Missions, technology, roadmap

La communauté française a une position forte en exo-planétologie comparée, et qui se consolidera davantage encore avec l'exploitation à venir de JWST, ARIEL, PLATO. Il est clair dès maintenant que l'étape ultérieure majeure pour le domaine, en préparation au niveau international, sera une mission spatiale de caractérisation d'exo-Terres (HWO, LIFE). Nous soulignons l'importance de la communauté sur le sujet, et l'intérêt d'une organisation et d'un positionnement coordonné maintenant et au cours des 5 années à venir en préparation de cet objectif à long terme. Cela inclut **l'identification et la montée en maturité d'éléments technologiques et de R&D** stratégiques.

- Presentation to ESA Science and Tech directorate *(Noordwijk, May 30th)* ; workshop en préparation 2024.
- US GOMAP
- **France, concertation HWO-LIFE : CNES, SF2A**

Multi-labs (> 30 proposants) message à prospective CNES

Missions, technology, roadmap

need to organize on long-term scales

Eléments de contexte internationaux

- US decadal survey
- ESA Voyage 2050

… et les travaux de structuration en cours :

- “Optimal Exoplanet Imagers” workshop *(Leiden, Feb 2023)*
- Presentation to ESA Science and Tech directorate *(Noordwijk, May 30th)* ; workshop en préparation 2024.
- US GOMAP
- **France, concertation HWO-LIFE : CNES, SF2A**

Multi-labs (> 30 proposants) message à prospective CNES

Start a European development program for technology validation

1. Coronagraphic systems
2. Wavefront sensing and control
3. Integral field spectrograph + spectroscopic data analysis
4. Polarimetry (science and technology)
5. Data analysis algorithms
6. Precision optics and detectors
7. Photonic technology

Wishes from HCI community:

- clear and visible long-term interest, coordinating on-going forces
- intermediate milestones for critical technology maturation (driven by HCI, useful for other applications)
- a strong position for upcoming opportunities, coordination with international community

Start a European development program for technology validation

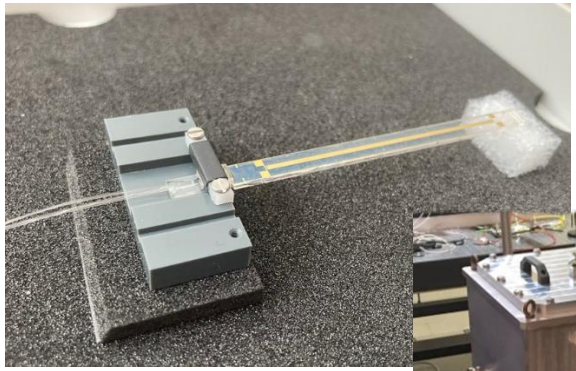
1. Coronagraphic systems
2. Wavefront sensing and control
3. Integral field spectrograph + spectroscopic data analysis
4. Polarimetry (science and technology)
5. ~~Data analysis algorithms~~
6. Precision optics and detectors
7. Photonic technology

Wishes from HCI community:

- clear and visible long-term interest, coordinating on-going forces
- intermediate milestones for critical technology maturation (driven by HCI, useful for other applications)
- a strong position for upcoming opportunities, coordination with international community

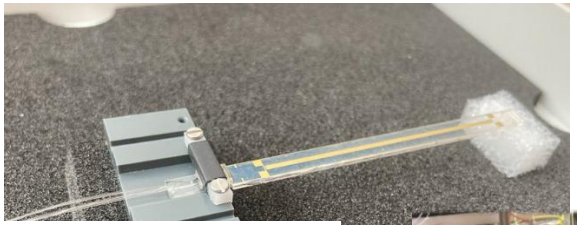
Importance of FOCUS-3 in the game

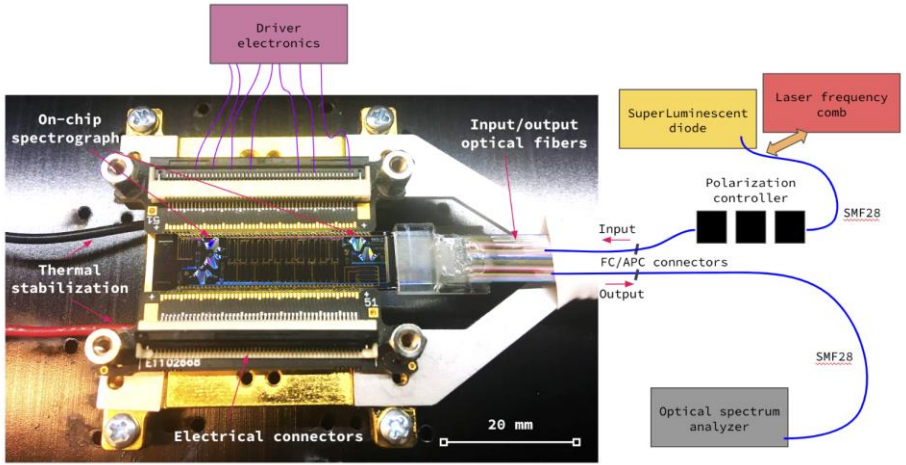
- Leverage capability has proven very efficient !
- Some high potential techno to mature:
  - Integrated optics functions: high accuracy phase and amplitude control, multi inputs/outputs + efficiency
  - Coronagraphy (robust and sensitive down to very short separation)
  - Spectral information: from chromaticity handling to high resolution information
  - Compact/robust/pixel-efficient optics+detector combination, including real-time sensing, servo-control and auto-calibration
  - Démonstration capacité hétérodyne IR sur télescope ?
  - Future detector needs : where are we ? What is achievable ?
- Grenoble + collaborators working network
- Training and visibility for long-term perspective



Importance of FOCUS-3 in the game

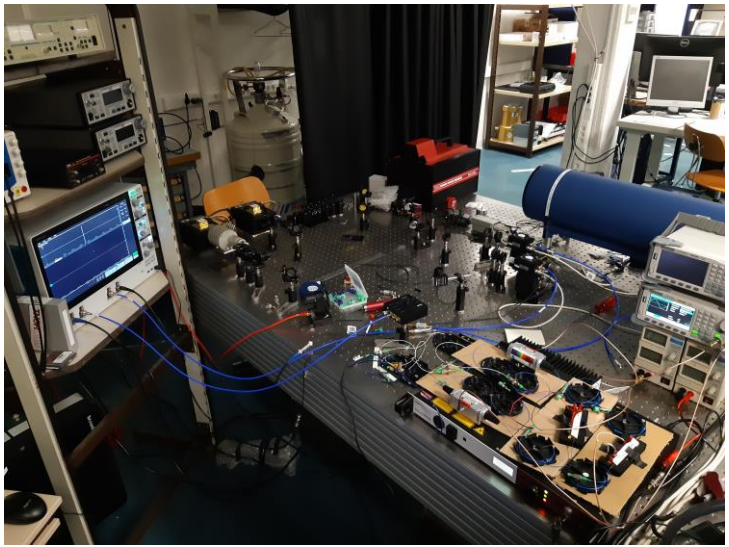
- Leverage capability has proven very efficient !
- Some high potential techno to mature:
  - Integrated optics functions: high accuracy phase and amplitude control, multi inputs/outputs + efficiency
  - Coronagraphy (robust and sensitive down to very short separation)
  - Spectral information: from chromaticity handling to high resolution information
  - Compact/robust/p combination, incl and auto-calibrati
  - Démonstration ca
  - Future detector n achievable ?
- Grenoble + collabo
- Training and visibili





Importance of FOCUS-3 in the game

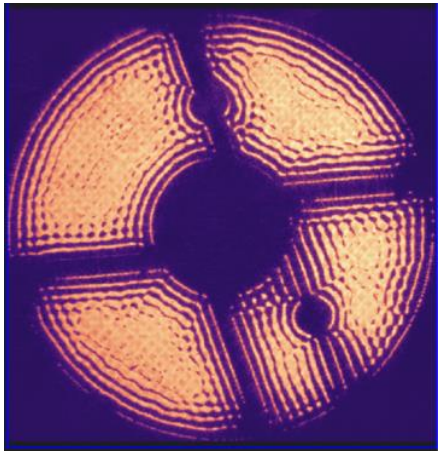
- Leverage capability has proven very efficient !
- Some high potential techno to mature:
  - Integrated optics functions: high accuracy phase and amplitude control, multi inputs/outputs + efficiency
  - Coronagraphy (robust and sensitive down to very short separation)
  - Spectral information: from chromaticity handling to high resolution information
  - Compact/robust/pixel-efficient optics+detector combination, including real-time sensing, servo-control and auto-calibration
  - **Démonstration of IR heterodyne on telescope**
  - Future detector needs : where are we ? What is achievable ?
- Grenoble + collaborators working network
- Training and visibility for long-term perspective



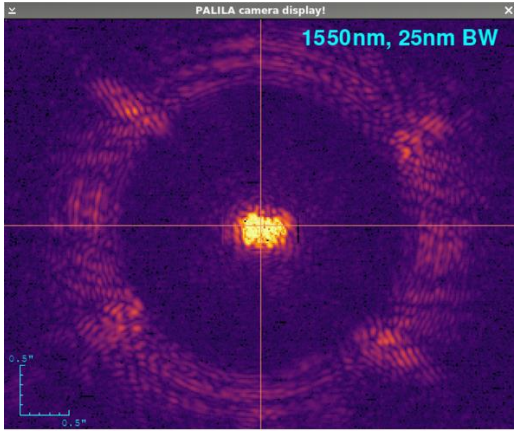
© T. Allain, J.P. Berger

Importance of FOCUS-3 in the game

- Leverage capability has proven very efficient !
- Some high potential techno to mature:
  - Integrated optics functions: high accuracy phase and amplitude control, multi inputs/outputs + efficiency
  - Coronagraphy (robust and sensitive down to very short separation)
  - Spectral information: from chromaticity handling to high resolution information
  - Compact/robust/pixel-efficient optics+detector combination, including real-time sensing, servo-control and auto-calibration
  - Démonstration capacité hétérodyne IR sur télescope ?
  - Future detector needs : where are we ? What is achievable ?
- Grenoble + collaborators working network
- Training and visibility for long-term perspective



© L. Leboulleux. Tests at Subaru



Importance of FOCUS-3 in the game

- Leverage capability has proven very efficient !
- Some high potential techno to mature:
  - Integrated optics functions: high accuracy phase and amplitude control, multi inputs/outputs + efficiency
  - Coronagraphy (robust and sensitive down to very short separation)
  - Spectral information: from chromaticity handling to high resolution information
  - Compact/robust/pixel-efficient optics+detector combination, including real-time sensing, servo-control and auto-calibration
  - Démonstration capacité hétérodyne IR sur télescope ?
  - Future detector needs : where are we ? What is achievable ?
- Grenoble + collaborators working network
- Training and visibility for long-term perspective

- Still need for large format IR matrices
- Mid-long IR low/no noise detectors ???
- (Very) fast IR detectors:
  - Sensors (up to 10kHz, moderate format)
  - Nulling detectors (no noise,mono pixels)
  - Heterodyne (mid IR, very fast)
- Potential of NIR MKIDS ?
- Space environment ?
- Very fine characterization

Importance of FOCUS-3 in the game

- Leverage capability has proven very efficient !
- Some high potential techno to mature:
  - Integrated optics functions: high accuracy phase and amplitude control, multi inputs/outputs + efficiency
  - Coronagraphy (robust and sensitive down to very short separation)
  - Spectral information: from chromaticity handling to high resolution information
  - Compact/robust/pixel-efficient optics+detector combination, including real-time sensing, servo-control and auto-calibration
  - Démonstration capacité hétérodyne IR sur télescope ?
  - Future detector needs : where are we ? What is achievable ?
- Grenoble + collaborators working network
- Training and visibility for long-term perspective

From technological new capabilities

Detectors and pre-optics optimized closely together

R&D and prototyping demonstrators

To game-changer novel instrument concepts